BEEF PRODUCTION FROM PASTURE SYSTEMS, WITH AND WITHOUT LEGUMES, IN THE WET-DRY TROPICS OF BRAZIL

BY

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IF
ONE SHOULD WAIT
TILL ONE CAN WRITE WITHOUT ERROR
NOTHING WOULD EVER BE WRITTEN
Cardinal Newman

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Abstract of Dissertation Presented to the Graduate Council
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BEEF PRODUCTION FROM PASTURE SYSTEMS, WITH AND WITHOUT LEGUMES, IN THE WET-DRY TROPICS OF BRAZIL

By

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Chairman: G. O. Mott
Major Department: Agronomy

Grazing trials were conducted in central Brazil to measure the effects of pasture attributes on beef production.

In the first grazing trial, located in the state of Minas Gerais, the area was cleared from the original cerrado vegetation and planted with a local cultivar of guineagrass *Panicum maximum* cv 'Guiné' with N fertilizer (100 kg N/ha) or with a mixture of legumes (*Macroptilium atropurpureum*, *Glycine wightii* and *Stylosanthes guianansis*). The experimental animals used were Gir x Holstein steers, and the pastures were grazed under the adjusted stocking-rate method. A completely random design was used with three replications.

The results showed that N fertilization of the grass pasture resulted in a stocking rate significantly higher than the grass-legume treatment. Animal performance was markedly affected by treatment and seasonal conditions.

Grass-legume and N-fertilized grass pasture produced gains up to 453 and 547 kg/ha/ year, respectively. When each season was considered separately, there was essentially no difference in the daily gain per animal between the two treatments. Glycine wightii was the most persistent of the legumes in this experiment. Calcium, P and protein of the forage removed by the steers were not limiting the cattle growth in the fertilized pastures.

An attempt was made to assess the economic viability of beef production from the two pasture systems. Both systems were very sensitive to beef prices and cost changes.

In the second grazing trial, animal production and pasture attributes were studied at the ranch level in the state of Goiás, Brazil, over a 2-year period.

The objective of the grazing study was to compare beef production on an improved pasture of green panic (P. maximum var. trichoglume) and legumes with fertilization vs. one which represented the common practice of unfertilized jaraguagrass (Hyparrhenia rufa).

The pastures were arranged in a completely random design. The cattle available for the experiment were Nellore and/or Nellore x Chianina steers.

The liveweight gain, expressed as an annual average for the 2 years, ranged from 161 kg/ha for the unfertilized jaraguagrass system to 361 kg/ha for the fertilized grass-legume system. A mean stocking rate of 2.38 steers/ha was carried over the 2 years of the trial for the grass-legume mixture. For the jaraguagrass a stocking rate of only 1.52 was achieved.

Centrosema pubescens had a higher persistence and contributed to higher animal production in the grass-legume pasture. Starting with 36.8% in the pasture, *Stylosanthes guianensis* decreased with each successive seasonal sampling. This was partly due to the infestation of fungal disease or the grazing management imposed. All the forages, except jaraguagrass, met the P and K requirements of grazing cattle for production. Calcium, Mg, Mo and Co were adequate in all forages studies. Forage Cu during the wet season was only 1.67 ppm for the jaraguagrass, which was below minimum requirements. Forage Zn was also below minimum levels.

Green panic had borderline deficient protein levels, while jaraguagrass was below the critical level, in both seasons. The legumes had higher IVOMD than grasses.

The level of animal production which can be attained in grass-legume systems in the Brazilian cerrados is dependent upon the legume content of the pastures, the level of available nutrients, and grazing management.

The improved pasture system technology that was used produced highly productive pastures in the cerrado region of central Brazil. The results from the experiments are fairly comparable to those obtained from tropical pasture species in different locations within the tropical world.

CHAPTER I

INTRODUCTION

The seasonal pattern of rainfall distribution and the soil fertility level are factors restricting forage production and quality in the wet-dry tropics of Brazil.

The beef-cattle industry in this region of Brazil has long experienced periods of abundance and scarcity of feed. Cattle production in these areas is limited by the feed supply during the dry season. The major effect of the dry season is low weight gain per animal per year.

Legumes are the key to successful development of pastures in central Brazil because soil N levels are low and presently the use of N fertilizer in this environment is not economical. Research done in central Brazil has shown an increase in forage nutritive value and dry matter yield when pastures were fertilized with N. However, the increase in yield due to N fertilization was not sufficient to provide for the requirements of the animals during the entire year. In the dry season animals do not have feed of adequate quality to fullfil their minimum requirements for energy and protein. Therefore, a system which combines fertilization with the use of tropical legumes to provide pasture during the dry season is needed. Legumes should provide increased quantities of nutritious forage during, at least, part of the dry season. This would mean that the "effective" dry season would be shortened and its overall effect would be reduced. This would also mean that the carrying capacity and productivity of the land would be increased during the dry season.

If grass-legume pastures can economically improve animal productivity in the cerrados of Brazil, the impact will be great considering the large amount of land involved.

The objectives of this research were:

1. To evaluate pasture systems using grasses and/or legumes for the wet-dry tropics of central Brazil and to determine their persistence, productivity and quality when grown on poor soils without and with fertilization.
2. To determine the proper management of adapted forage species in order to provide optimum year-round nutrition to the grazing animal.
3. To measure the results of grass-legumes associations in terms of forage production, botanical composition of the forage on offer, liveweight gains per animal, animals per hectare, and liveweight gain per hectare. And to evaluate the nutritive value of the forage on offer, sampled during the dry and rainy seasons, in terms of crude protein, *in vitro* organic matter digestibility, and selected minerals.

CHAPTER II

REVIEW OF LITERATURE

Description of the "Cerrado" Region in Central Brazil

Vegetation

Within the general vegetation class termed "cerrado" Brazilian phytogeographers and others working in this area generally distinguish four types of vegetation based on ecological and physiognomic (structural) points of view. Cerrado is the principal vegetation of most of Brazil. The Portuguese word "cerrado" means literally "half-closed," "dense." The name is particularly appropriate because this vegetation is neither open nor closed. Typically, cerrado is a variable mixture of small trees with a fairly well developed ground layer. The Brazilian nomenclature is used here because it is well accepted and is unambiguous and appropriate. The nearest international equivalent is the word savanna. According to Goodland (1971), the dominance of the woody vegetation in cerrado constitutes a "fundamental difference between the cerrado and the floristically somewhat related vegetation of the llanos of Colombia (Blydenstein, 1967) and Venezuela (Blydenstein, 1962) and the savannas of northern South America (Beard, 1953; Vareschi, 1966; Ramia, 1967). Similarly, campo (Sampaio, 1938; Cosmopolitan World Atlas, 1962) and grassland (Pratt, Greenway & Gwynne, 1966) are also inappropriate.

Cerrado is a fairly uniform type of vegetation geographically and floristically; however, it varies physiognomically from herbaceous, grassy, shrubby through woodland, almost to forest. The classification of the gradient adopted here is based on that used by people of central Brazil (Eiten, 1963, 1968). This change from little more than grassland to almost forest has been arbitrarily divided into four kinds for convenience only. These are called "campo sujo," "campo cerrado," "cerrado" and "cerradão." A summarization of these types follows.

"Campo sujo" means "dirty field," an area of field or herbaceous vegetation, but with woody plants, shrubs or very small trees, scattered sparsely throughout.

"Campo cerrado" means "half-closed field." In campo cerrado, the trees are taller and denser than in campo sujo. It is not sufficiently dense to reduce the ground cover, which remains as dense and as tall as in campo sujo.

"Cerrado," sensu strictu, is the third kind of cerrado, sensu lato, and is perhaps the most typical or central of the variants. This is primarily a woody type of vegetation, consisting mainly of trees. The trees are denser and taller than in campo cerrado, and support a well-developed canopy. The ground layer may be slightly sparser than in campo cerrado, probably due to the denser canopy.

"Cerradão" is the fourth kind of cerrado vegetation. The suffix "-ão" in Portuguese forms the augmentative, thus here means "big cerrado." Cerradão is a type of forest. The trees are tall and dense, and support a dense canopy. The trees are somewhat denser than in cerrado and much greater in girth. The ground is more often bare or litter covered. The "cerradão" of the state of Goiás is popularly called "mata de terceira classe" ("third-class forest"), and Rizzini & Heringer (1962) called it "floresta xeromorfa semi decidua."

Another classification of cerrado by Eiten (1963, 1972) includes one category called "campo limpo" which means "clean field," an area of grassy or herbaceous aspect without woody plants rising above the ground layer.

There is no detailed vegetation map of the cerrado; however, all of the types discussed above occur in all areas of cerrado. Cerradão is preferentially used for agriculture because of its occurrence on richer sites. Fire is thought to be important in the ecosystem, and possibly increases in frequency from cerradão to campo sujo.

From the structural point of view, a normal gradation in vegetation in this area goes from campo limpo (including "campo sujo"--dirty field) to campo cerrado, cerrado, cerradão. The physiognomic gradient of cerrado vegetation in central Brazil has been found to parallel a soil fertility gradient (Goodland and Pollard, 1973).

Probably one of the most complete studies about "cerrado" vegetation was published by Eiten (1972). After a complete discussion of all previous work related to theories about origin of "cerrado" vegetation, he concluded that:

> The cerrado is a climax vegetation dependent upon the correct range of climate, topographic position and soil. The

> cerrado is a semideciduous xeromorphic vegetation dominant in central Brazil, occupying about 20% of the whole country or 40% of the non-Amazonian part. (Eiten, 1972, p. 326)

There are 183 million hectares under the vegetation called cerrado, in Brazil, from the northern territory of Amapá to as far south as the state of São Paulo. The major portion of the cerrado is in the central part of the country in the states of Minas Gerais, Goiás, Mato Grosso and the Federal District, where Brasilia is located (Ferri, 1976). This huge region is being utilized in an extensive system of cattle production, with the exception of relatively small areas where an intensive agriculture is practiced (see Fig. 1).

Climate

The climate of the cerrado area is seasonal, the "AW" type of Koppen (Galvão, 1960), with half of the total annual precipitation of 1,600 mm falling in the months of November to January. Most of the cerrado is subject to a severe 6-month dry season, during which time much of the ground layer appears desiccated in all four cerrado types.

The average annual temperature of the cerrado region is 20-26° C (Eiten, 1972), but in southern São Paulo it is as low as 18° C. Rainfall varies from a yearly average of 750 to 800 mm on the dry side of the cerrado region (northeast side) to 2,000 mm on the wet side. There is a great variation not only in average precipitation but also in the distribution over this vast region. Water-deficit determinations by the method of Thornthwaite for soils

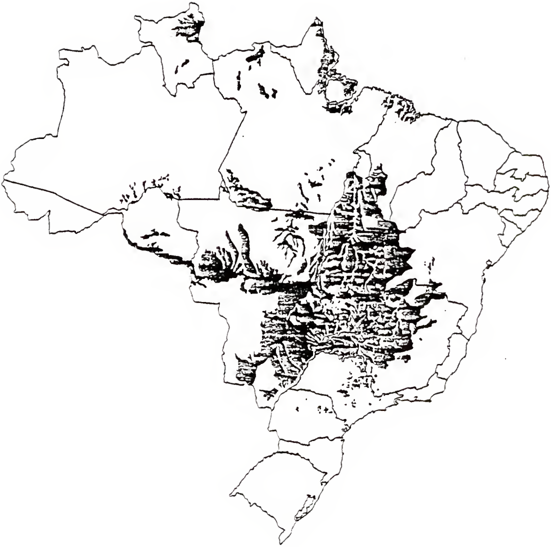

Fig. 1. The "cerrado" is a semideciduous xeromorphic vegetation dominant in central Brazil and occupying about 1.8 million sq km, 20% of the whole country or 40% of the non-Amazonian part.

under cerrado vegetation in Brazil can vary from 4 to 791 mm according to data presented by Reis (1971).

A typical annual distribution of precipitation and potential evapotranspiration for Brasilia is shown in Fig. 2. The average annual rainfall of 1,626 mm shown for Brasilia is representative of a large area under cerrado vegetation in Brazil. The length and severity of the dry season, however, is another very important characteristic in this region. During the dry period, that normally extends from May to August, only irrigated crops can be grown except for some forage grasses and tropical legumes.

Even during the months of December and January, those highest in rainfall intensity, it is not uncommon to experience 2 weeks of rainless days. These are often associated with high solar radiation and high potential evapotranspiration (Wolf, 1974). They are known locally as "veranicos" and drought-sensitive crops can be seriously injured when no irrigation is available.

Geology

Brazilian geographers refer to the Central Plateau in Brazil as the highlands between the Rio São Francisco in the east, the Rio Grande tributary of the Paraná in the south, and the Araguaia, a tributary of the Tocantins, in the west.

The Central Plateau of Brazil consists mainly of a core of ancient (pre-Cambrian) intrusive crystalline rocks (granite and gabbro) and metamorphic rocks (gneiss, schist, phyllite and quartzite), which are partly exposed and partly overlain by younger Paleozoic and

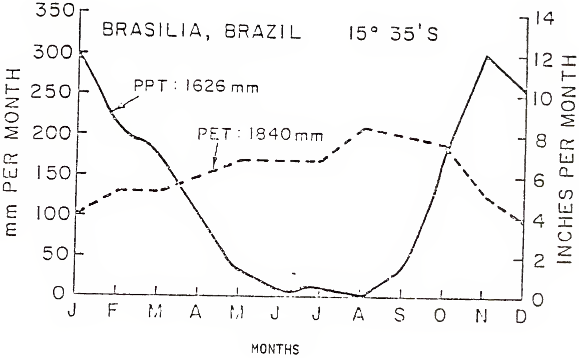

Fig. 2. Distribution of monthly rainfall and potential evapotranspiration in Brasilia, which is representative of a large area under "cerrado" vegetation in Brazil. PPT = precipitation, PET = potential evapotranspiration. Annual totals in numbers.

Mesozoic sedimentary materials (AIA, 1963). Most of the area has been uplifted several times and then dissected and leveled by successive cycles of erosion. The undissected remnants of these erosion surfaces form tablelands and rolling plains of varying sizes.

Among the main surface features of tropical America, the Guyana and Brazilian shields are the oldest land surfaces. They originated during the Archean and Paleozoic periods and consist mainly of granite and gneiss partially covered by stratified rocks, mainly sandstone (Sánchez, 1976). Large areas of the central plateau of Brazil have gently undulating topography where two or three erosions surfaces can be seen. These have been described by Cline and Buol (1973).

Soil Characteristics

Soil taxonomy. According to FAO (1971), the total area under cerrado vegetation in Brazil comprises 1.8 million sq km, 20% of the whole country. Soils under cerrado vegetation in Brazil may be classified into at least 13 great groups according to the Soil Classification nomenclature used in Brazil (Ranzani, 1971). This author suggests that the Red-Yellow Latosol and Dark-Red Latosol are predominant in this area. The distribution of the main great groups and subgroups according to FAO nomenclature with the approximate equivalent U.S. Taxonomic System and Brazilian nomenclature is summarized in Table 1. The geographic distribution of the main soils under "cerrado" and forest vegetation in central Brazil is shown in Fig. 3 .

Table 1. Area of soil great groups and subgroups under "cerrado" vegetation in Brazil based on FAO Soil Map of the World with approximately equivalent U.S. System and Brazilian nomenclature

Area (%)	FAO Nomenclature	U.S. System	Brazilian Nomenclature
2.1	Orthic Acrisols	Tropustult	Red-Yellow Podzolics
2.9	Orthic Ferralsols	Haplustox	Dark-Red Latosols
4.6	Rhodic Ferralsols	Eutrustox	Dusky-Red Latosols
13.8	Lithosols	Lythic Dystropepts	Lithosols
18.1	Ferralic Arenosols	Quartzipsamment	Red-Yellow Quartz sands
21.1	Plinthic Acrisols	Plintic Tropustult	Hydromorphic laterites
37.3	Acric Ferralsols	Acrustox	Latosols

Source: Sánchez, 1976.

Most of these soils are deep with no physical restrictions to normal root growth for plants of economic importance. Occasionally a laterite layer occurs at variable depth or, in a few cases, massive lateritic material is found (Feuer, 1956; Cline & Buol, 1973).

A number of soil properties consistently lead to a common parameter of low natural fertility. They are acidity, low cation exchange capacity (CEC), low base saturation, high P fixation, Al saturation, highly weathered clay minerals, and low water-holding capacity. There is, however, extreme variation in textural characteristics in these soils (Verdade, 1971; Ranzani, 1971). Soils under cerrado vegetation in Brazil can go from extremely sandy to extremely clayey, passing through all intermediate steps. This seems to be one of the main parameters that should differentiate these soils as to their management. Changes in texture have been related to differences in P fixation and water retention.

Tropical Grass-Legume Evaluation and Productivity

Production from Legume-Based and Nitrogen-Fertilized Pastures

The potential liveweight beef production in relation to the dry matter yield of N-fertilized tropical grasses has been recognized for some time (Vicente-Chandler et al., 1959, 1961; Mott et al., 1965; Quinn et al., 1965; Quinn et al., 1970; Caro-Costas et al., 1961, 1965; Aronovich et al., 1970; Evans, 1969, 1970b).

Data from beef production on legume-based pastures indicate a range of liveweight gain per hectare from 200 kg at the drier end of

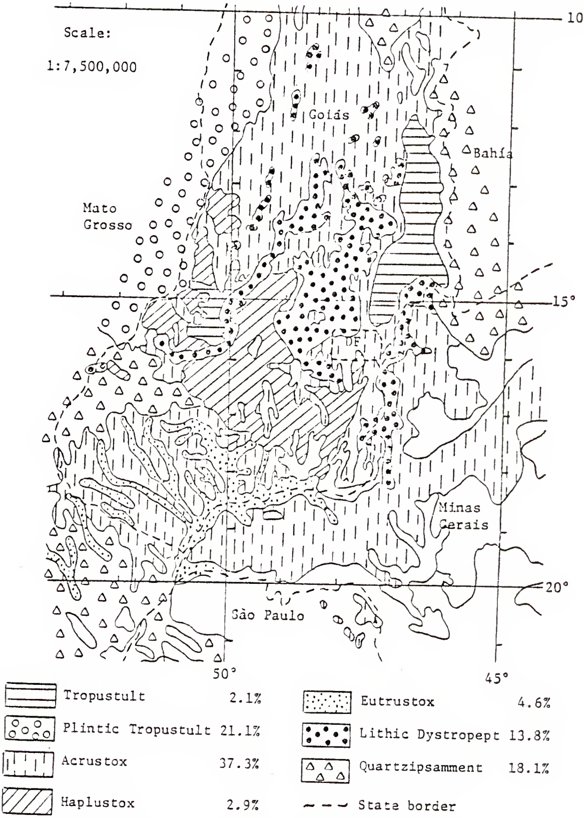

Fig. 3. Main soils under "cerrado" and forest vegetation; based on FAO, 1971.
Source: Lopes, 1975.

the scale (Oyenuga and Olubajo, 1966) to 740 kg in a 1,250-mm rainfall area, long growing season environment at Serere, Uganda (Stobbs, 1969d). The upper level of production under experimental conditions appears to lie in the 700 to 750 kg liveweight gain (L.W.G.) per hectare range. Under commercial conditions L.W.G. per hectare in the range of 500 to 550 kg may be achieved (Davidson and Martin, 1965).

Data demonstrate the importance of maintaining an adequate proportion of legume in the pasture, in order to achieve high levels of production on legume-based pastures (Evans, 1970a; Bryan, 1968b). Phosphorus nutrition is also important to legume maintenance and for animal nutrition. It is difficult to draw conclusions regarding species, because it will depend on available soil nutrients and other factors.

In northern Queensland, Australia, when *Desmodium intortum*, *Desmodium uncinatum*, *Stylosanthes guianensis*, *Vigna luteola*, and six *Glycine wightii* cultivars were sown in mixture with green panic grass (*Panicum maximum* var. *trichoglume*) and each mixture given 0 and 400 kg ordinary superphosphate/ha annually and grazed for 3 years, Gartner et al. (1974) found that green panic was dominant in the first 2 years, but legume yields increased in the third year, particularly on plots with superphosphate. They noted that, although *D. intortum* and *D. uncinatum* were adapted to the area, their ability to respond to the conditions of the environment was limited by insect attacks.

In Queensland, Evans (1970) found that, when different subtropical grass-legume mixtures were grazed at high stocking rates, the level of animal production was closely associated with the legume content of the pasture, with the legume portion of the mixture decreasing over a 3-year period. With a low stocking rate, the legume content was maintained at a higher level, but gains per hectare were lower than at a higher stocking rate. He also pointed out the beneficial effect of annual phosphate dressings on the increase of legume content and of liveweight gains at all stocking rates.

Stobbs (1969b) tested three- and six-paddock rotational and continuous grazing systems on a mixture of *Panicum maximum* and *Macroptilium atropurpureum* for 4 years and found the highest animal production from the three-paddock rotational and from the continuously grazed pastures. Only when the quantity of available forage was low did the rotational grazing treatments show advantage over continuous grazing. Continuous grazing resulted in higher legume content, whereas rotational grazing resulted in higher grass and lower weed contents. It was also concluded that the inclusion of the nutritious, drought-resistant *M. atropurpureum* into the pasture mixture contributed considerably in extending the availability of quality forage during the dry season.

On rotationally grazed *Centrosema pubescens*-*Cynodon plectostachyus* pastures in Nigeria, 300 kg gain/ha/year were achieved and the combination was regarded as truly perennial under this stocking regime (McIlroy, 1962). Vigorous *Desmodium intortum*-pangola pastures in Hawaii receiving adequate nutrients have produced liveweight gains of 896 kg/ha/annum, compared with a mere 22 kg/liveweight gain/ha prior to the development of the legume-grass pasture (Younge & Plucknett, 1965). In Uganda, pastures based on *Centrosema pubescens* and *Stylosanthes gracilis* produced 526 kg gain/ha, compared with 127 kg/ha. from similar pastures without the legumes (Stobbs, 1965). Furthermore, on all-grass pastures the production declined over a 3-year period, whereas the production on the grass-legume pasture increased with age.

Keya (1974b), in Kenya, found that *Setaria sphacelata*/*Desmodium intortum* or *D. uncinatum* mixtures yielded dry matter quantities and crude protein contents which were similar to those of pure grass stands fertilized with 100 to 200 kg and 200 to 400 kg of N/ha/year, respectively.

Grazing modifies the opportunity that tall or climbing plants have for shading shorter plants. *Stylosanthes humilis*, *Trifolium repens*, and *Lotononis bainesii* (Bryan et al., 1971) are shaded by taller companion grasses if heavy grazing pressure does not remove the companion grass to allow light into the canopy. On the other hand, dominance of climbing or tall legumes is generally promoted by lenient grazing pressures.

Tothill (1974), in Australia, reported 3 years' results of sod-seeding of Siratro (*Macroptilium atropurpureum*) into native Australian speargrass. He compared (a) unimproved woodland, (b) natural speargrass (*Heteropogon contortus*), (c) natural speargrass plus Siratro oversown with P and Mo (molybdenum) and (d) buffelgrass (Cenchrus ciliaris) plus Siratro plus P and Mo sown on completely cleared land. In the first year, liveweight gains were greatest in (d). Oversowing with Siratro gave a four to tenfold increase in liveweight gains per unit area and one to twofold increases in gain per head.

Mellor et al. (1973), in a 4-year grazing trial in Australia, studied four cultivars of Panicum maximum, each in mixture with Centrosema pubescens or with C. pubescens and Glycine wightii cv. Tinaroo at approximately the same grazing pressure. Common and Hamil guineagrasses were found to be the best cultivars of P. maximum and there were no overall advantages from growing a mixture of legumes with the grasses as compared with C. pubescens alone, although the inclusion of Tinaroo glycine with C. pubescens resulted in increased liveweight gains in autumn and winter.

Winks et al. (1974) reported on a 4-year grazing trial where two stocking rates were compared on a Stylosanthes humilis/ natural grass pasture with and without superphosphate. They found that P fertilization increased the yield and quality of herbage and the liveweight gains. Liveweight gains per animal were greater at the lower than at the higher stocking rate.

Cohen and O'Bryan (1974), in a 4-year grazing trial in Australia, studied a natural Australian pasture dominated by Axonopus affinis and Bothriochloa decipiens with (a) no fertilizer, (b) superphosphate plus Trifolium repens, and (c) superphosphate plus

Lotononis bainesii, *Macroptilium atropurpureum*, *Lespedeza striata*, and *T. repens*, all under three different stocking rates. Cows grazing (b) and (c) maintained higher liveweights and produced more and heavier calves. Conclusions were that P application and oversowing could increase stocking rates, liveweight gains, and fertility of beef cattle grazing natural pastures of the area. Similar results were also obtained by Lowe (1974) who found that liveweight gains of cattle grazing natural pastures oversown with *Macroptilium atropurpureum* were greater than of those grazing unimproved pastures. Oversowing also allowed the stocking rate to be increased.

't Mannetje (1974) studied the relationships between pasture attributes and liveweight gains on a subtropical pasture of *Cenchrus ciliaris* (a) without N, (b) with N, and (c) with *Macroptilium atropurpureum*. Liveweight gains of steers were related to total green matter, green grass, or green legume, and no relation could be found between liveweight gains and total dry matter, digestible dry matter, total N or digestibility or percentage N of green material. It was suggested that the feeding value of the grass-legume mixture was sufficient to finish cattle for much of the year, and crude protein levels of the green forage were always high enough not to restrict intake and to keep the animals in a positive N balance.

Jones (1974) compared *Setaria anceps* cv. Nandi with (a) N fertilizer, (b) Greenleaf desmodium (*Desmodium intortum*), and (c) *Macroptilium atropurpureum* cv. Siratro, during a 4-year grazing trial in Australia. Maximum annual liveweight gains per hectare for the pasture were desmodium (243 kg), Siratro (233 kg) and fertilized pastures (475 kg). At the stocking rate of three steers per hectare, the legume pastures were severely over-grazed by the end of the fourth year, and legume production declined to virtually zero. Results indicated that for maximum gain per hectare, the stocking rate for the legume-based pastures was about two steers per hectare, and for N-fertilized pastures it was five steers per hectare. It was also shown that the legumes would recuperate in the grass-legume pastures if grazing were stopped for some time.

Seasonal effects. A number of grazing trials in the tropics indicated seasonal variations in the weight gains of cattle and performance with different grass species. Carrera and Ferrer (1963) reported that the weight gains of Zebu cattle grazing jaraguagrass (*Hyparrhenia rufa*) in Mexico averaged 185 to 199 kg/ha/year over a two-year period. Carrera (1966) indicated later that the steers grazing jaraguagrass showed the smaller rate of daily gain, 248 g compared to 550 g for pangolagrass, over a 3-year period. Arroyo and Teunissen (1964), working with Zebu steers in a "put-and-take" grazing trial in Mexico, found that the gains in weight from July to January varied with the forage species. The gains with jaraguagrass were 190 kg/ha, compared to 150 and 406 kg/ha for guineagrass and pangolagrass, respectively. Carneiro et al. (1966) in Brazil pointed out that the average daily weight gain per animal was 282 g for the dry season compared to 528 g during the rainy seasons. The animals were on jaraguagrass pastures during both seasons but received some additional feed during the dry season.

Fertilization can influence animal performance in the tropics; however, it seems that seasonal variations prevail under all circumstances. Quinn et al. (1963) reported that the daily weight gain of Zebu steers during the dry season in central Brazil varied from 77 to 175 g with fertilized grasses compared to 4 to 40 g without fertilizer. For the rainy season, the variation was from 570 to 813 g with fertilization compared to 588 to 804 g without fertilization. Combined results for both seasons showed that the live weight gains per unit area for animals grazing jaraguagrass were greater than any other grass with or without fertilization. With fertilization the jaraguagrass produced 448 kg of liveweight gain per hectare and 249 without fertilization. However, the gains during the dry season were only 5.7 and 0.3% of those during the rainy season with and without fertilization, respectively.

The inclusion of a legume in a grass sward can also influence animal performance under grazing in the tropics, but again the season of the year can be a limiting factor. Stobbs (1965) found that the inclusion of Stylosanthes guianensis or Centrosema pubescens with three tropical grasses including jaraguagrass, increased annual liveweight gains of Zebu cattle by 14 to 41%. He stressed the value of the legume during the dry season, the inclusion of which increased liveweight gains from about 188 to about 470 kg/ha/year. Stobbs and Joblin (1966) indicated later that the liveweight gain of Zebu cattle in Africa increased from 289 to 401 kg/ha during the dry season and from 1599 to 1823 kg/ha during the rainy season when Centrosema pubescens was included with jaraguagrass pastures under grazing conditions. These reports seem to indicate that protein was probably the limiting factor for cattle performance and the legumes were able to provide the necessary protein even though there was a limitation in the availability of water during the dry season.

Grass and Legume Response to Nutrients

Phosphorus. Response to phosphate fertilizers in soils under cerrado vegetation in Brazil has been reported. One of the first experiments on P response in forage crops grown in these soils was reported by McClung and Quinn (1959). In a sandy loam soil derived from Bauru sandstone in São Paulo, they obtained a considerable yield response to 100 kg P_2O_5/ha with batatais grass (Paspalum notatum). When this was applied in combination with 40 kg of S/ha, a sixfold increase in dry matter production was observed.

Considerable yield response to P fertilizers with four tropical legumes (Stylosanthes guianensis, Centrosema pubescens, Glycine wightii, and Macroptilium atropurpureum var. Siratro) was reported by Jones and Freitas (1970). Similar results were obtained by França and Carvalho (1970) in greenhouse studies involving five tropical legumes (Glycine wightii L. var. Common, Glycine wightii L. var. Tinaroo, Macroptilium atropurpureum D.C. var. Siratro, Pueraria javanica Benth and Centrosema pubescens Benth). With a Red-Latosol from Sete Lagoas, Minas Gerais (containing 0.75 mg P_2O_5/100 g) a no-P control treatment yielded 0.92 g of dry matter as compared to 4.64 g for the complete treatment. The P deficiency also was reflected in decreased nodule weight and N production.

Neme and Lovadine (1967), in a 6-year field experiment with perennial soybean (Glycine wightii L.), found that a combination of 120 kg P_2O_5 plus 6 metric tons of lime/ha gave a large increase in yield.

Teixeira et al. (1971), working with soil and samples of natural pasture from three farms near Morrinhos, Southern Goiás, observed that the available P levels in the soil (around 1.5 ppm P) were very low. This low natural P availability resulted in the grass P content below the suggested critical level of 0.15% for normal development of adult cattle. Werner and Monteiro (1974) and Werner (1975) reported substantial increased yields of Centrosema pubescens to P and K fertilization.

In the final analysis, the response of the legume to fertilizers must be measured in the grass-legume association itself, since the competition for nutrients by the associate grass may modify considerably the fertilizer requirements of the grass component. This has been well illustrated in the K nutrition of Desmodium intortum growing with or without Setaria anceps, where the legume yield in the mixture was greatly dependent upon the K fertilizer (Hall, 1971).

Micronutrients. Forage crops grown on cerrado soils have responded differently to micronutrients. Britto et al. (1971) found that, in a Dark-Red Latosol from Brasilia, Federal District, treatments with no Zn tended to have a smaller green mass from perennial soybean Glycine wightii L. than one which received a rate equivalent to 20 kg of $ZnSO_4$/ha. Observable effects also resulted from the application of an equivalent to 1 kg of ammonium molybdate/ha. Similar responses were obtained by Santos (1971) working with three Latosols from Sete Lagoas, Minas Gerais with perennial soybean. Applying Zn in a nutrient solution increased dry matter production in one out of two clayey Dark-Red Latosols but had no effect on a clayey Red-Yellow Latosol.

Legumes have a specific requirement for Mo and Co for the process of N fixation. Deficiencies of these elements lead to symptoms similar to N deficiency. Sulfur deficiencies and responses to S in these soils have also been reported for many crops. One of the first studies involving S in these soils was carried out in the greenhouse by McClung and Freitas (1959). Working with ryegrass and alfalfa using the technique complete minus one, S was second only to P as a nutritional factor affecting the growth of grasses.

Legumes require relatively large amounts of P for nodule formation and N fixation. Phosphorus deficiency may limit N fixation before effects are shown on plant growth. The long-term effects of superphosphate application on N accumulation in the field from legume N fixation was demonstrated by Henzell et al. (1966). Andrew and Robins (1969a,b) have determined the critical percentage of P for the growth of a range of tropical legumes. These values were based on whole plant tops sampled in the immediate preflowering stage of growth. The critical percentage is the element concentration in plant tops below which reduced plant growth is recorded. The P work by Andrew and Robins (1969a) demonstrated the ability of *Stylosanthes humilis* to absorb greater quantities of P from soils with low available P than other tropical legume species. It was suggested by Possingham et al. (1971) that the ability to absorb P from low status soils may be related to the presence of endotrophic mycorrhiza associated with the plant roots in a number of tropical legumes (*Stylosanthes humilis*, *Macroptilium atropurpureum* and *Leucaena leucocephala*).

The Grass-Legume Balance

Persistence of tropical and subtropical legumes.

The first requirement for successful use of high-yielding legumes for animal production under grazing conditions is their successful adaptation to local climatic conditions. Secondly, their nutrient requirements must be met to ensure high yield and maintenance. Finally, and most importantly, they must persist under grazing to secure a long-lasting beneficial contribution to the companion grass, to the soil, and to the grazing animal.

The lack of persistence of tropical and subtropical legumes under grazing conditions has been a major factor limiting their use in pastures. Because of the great importance that tropical and subtropical legumes could have in animal production, many investigators have conducted clipping and grazing experiments in attempts to find management systems compatible with legume persistence under grazing.

Roberts (1974) indicated that the factors which influence the stability of a grass-legume mixture are (a) relative growth rates of the grass and of the legume, (b) palatability of the grass and of the legume, (c) maximum height of the grass, (d) shade tolerance of the legume, (e) seedling regeneration, and (f) ability to withstand trampling. He suggested that continous grazing helps the legume to compete better with the grass under all the above conditions than it could under a rotational grazing system.

Jones (1971), cited by Roberts (1974), stated that the variable cutting or grazing interval has had the most dominant influence on total legume and total pasture yield and that "it is reasonable to conclude that rapid rotational grazing would result in lower legume yields than in slow rotational systems in which the recovery time was eight weeks or longer" (p. 65).

Lack of legume persistence is attributed to the use of unadapted species, incorrect or no fertilization, the lack of suitable Rhizobium and overgrazing ('t Mannetje, 1978). In the case of the twining or scrambling legumes such as Siratro, desmodium and glycine, frequent defoliation results in low yields, whereas slight defoliation or absence of defoliation results in higher yields and a higher contribution of legume yield to total pasture yield (Jones, 1967; Whiteman, 1969). Not only the frequency of cutting or grazing, but also the height of defoliation, can have a very large influence on the botanical composition of the pasture and the yield of legume produced. With Desmodium intortum, the highest yield was given under infrequent cutting at a low cutting height; but the lowest yield under frequent cutting at the same height (Jones, 1971). It was demonstrated that increasing the cutting height increased the legume percentage in the harvested material, irrespective of the influence of this treatment on total pasture yield. Frequent and severe defoliation reduced both legume percentage and total legume yield in experiments with Siratro and D. intortum. The residual effect of severe cutting in the Siratro pastures was most apparent in the season after treatment effects ceased, with the effect being due mainly to a reduction in the number of legume plants per square meter. However, there was also an additional effect on individual plant vigor (Jones, 1971).

Unlike perennial twining legumes, annual Townsville stylo (Stylosanthes humilis) appears to thrive under heavy grazing, and with this legume, the grass-legume balance is governed mainly by stocking rate (Shaw and Norman, 1970).

Obviously, the response of the associate grass to grazing will modify the response by the legume. Thus, in Uganda, Hyparrhenia rufa and Panicum maximum decreased with increasing stocking rate and the associate legumes Stylosanthes gracilis and Siratro increased (Stobbs, 1970). Both of these grasses are palatable and sensitive to heavy grazing.

The method of grazing, as opposed to the overall stocking rate effects, has not been studied in any detail. However, Stobbs (1969b) reported higher legume contents in continuously grazed pastures than in pastures of Siratro-guineagrass grazed rotationally on a three- or four-paddock rotation.

Measurements in Forage Evaluation

The quantity and the quality of the forage available to the grazing animal throughout the year determine the potential of a particular region for animal production. Any forage evaluation procedure must include methods of evaluation of both the quantity and the quality.

Mott and Moore (1970) developed a scheme for forage evaluation consisting of five stages:

Stage 1: Introduction, breeding program
Stage II: Uniformity tests, environmental evaluation, small plot clipping
Stage III: Fertility studies, clipping management, response to grazing
Stage IV: Animal response, *in vivo* intake and digestibility, product per animal, product per hectare
Stage V: Development of feeding systems, pasture sequence, hay, silage, supplemental feed

The evaluation of quality in the first three stages involves an *in vitro* digestion procedure. Stages IV and V involve evaluation by animal responses in terms of intake and digestibility trials, and beef or milk produced per animal and on a per land area basis.

Where the final system is complex, it may be desirable to progress through all these stages. With a rather simple system or if the alternative components of a proposed system have been adequately evaluated in Stage IV, a complete system may be formulated and recommended for practice without additional research evaluation in Stage V. In instances where there is strong pressure for quick release and where adequate information is available on similar species, Stage III may be omitted, and, following Stage IV, a system can be recommended for on-farm use. It is recognized that evaluation in Stage IV may incorporate some factors ordinarily considered in Stages III and V.

Wheeler et al. (1973) suggested that the variable grazing method (put and take) would be the one of choice in Stages III and IV, i.e., to evaluate components of systems, whereas the fixed method might be expected to predominate in Stage V, studies of whole systems (Morley and Spedding, 1968).

Stocking Rate, Grazing Pressure, Carrying Capacity, and Their Relationship with Animal Production

The use of the terms stocking rate, grazing pressure, and carrying capacity occurs repeatedly in pasture-grazing research and should therefore be defined. Mott (1960) defined these terms that are essential to an understanding of grazing management principles:

Stocking Rate

Stocking rate is expressed as the number of animals per unit area of land, the term bearing no relationship to the amount of forage. McMeekan (1956) emphasized the importance of stocking rate compared to kind of grazing management systems and kind of animals in the conversion of pastures to animal products. Stocking rate is considered to be the most powerful factor influencing the efficiency of pasture conversion to animal products on a per unit area basis.

Riewe (1961) reviewed a number of stocking rate studies and found that, in most cases, a significant negative correlation existed between stocking rate and gain per animal. However, exceptions were found and the two most notable ones were that (1) the lightest stocking rate did not always produce the highest gain per animal, and (2) the heaviest stocking rate did not always produce the greatest gain per unit area.

As a general rule increases in stocking rate result in decreased gain per animal, but gain per unit land area is increased.

Grazing Pressure

Grazing pressure is defined as the number of animal grazing days per unit of available forage and has been proposed as the criterion for assessing the similarity of stocking rate treatments (Mott, 1960).

Because of differences in other management factors, it is possible to have treatments, at the same stocking rate, in which the animals have widely different amounts of pasture available to them for grazing. Thus one group of animals may have their intake limited through a shortage of available dry matter and by overgrazing their pasture in an attempt to maintain intake, while another group at the same stocking rate may have ad libitum intake and be allowing pasture to go to waste (Campbell, 1966).

Grazing pressure, then, may be considered a parameter that gives an assessment of the potential severity of defoliation and the ability of the pasture to supply the dry matter requirements of the animals.

In practice intake will probably fall as available dry matter declines below some critical level, and the rate of this decline in intake with increased stocking rate and reduced available dry matter will affect the grazing pressure/stocking rate relationship.

Mott (1960, p. 607) called attention to the fact that "in comparisons between plant species, species mixtures, fertility treatments, grazing management systems, and trials of similar nature in which animals are being used to measure the pasture output, it is imperative that the grazing pressure imposed on each of the treatments should be equal."

Carrying Capacity

Carrying capacity or grazing capacity is the stocking rate at the optimum grazing pressure. The number of animals days per unit area of land or the average number of animals for a given period of time is the measure which should express the yield of the pasture. The carrying capacity, if the stocking can be assumed to be near optimum, should be the investigator's best estimate of the production of the pasture in terms of animal numbers (Mott, 1960). Using an optimum grazing pressure a good estimate the potential production per animal and per hectare will be obtained.

The general relationships of increased stocking rate to production per animal and production per unit area have been extensively discussed in the literature. Generally, increasing the stocking rate up to some point results in a decrease in output per animal, but an increase in production per unit area (McMeekan, 1956, 1960; Harlan, 1958; Mott, 1960, 1973; Riewe, 1961, 1965; Hull et al., 1961, 1965; Petersen et al., 1965; Conway, 1965, 1968; Vivian, 1966; Browne and Walshe, 1968; Jones and Sandland, 1974; and Connolly, 1976). However, much controversy remains on the linearity or otherwise of the "true" relationship between stocking rate and animal gain. Harlan (1958) made the first attempt at expressing the generalized relationship between stocking rate and liveweight gain per animal and animal product per unit area. He divided the range of stocking rate into light, moderate, heavy, and very heavy. From his proposed "double exponential" equation for gain per animal he predicted the following: (1) one full degree of grazing increment beyond heavy stocking rate will invariably result in loss of weight; (2) livestock must either gain or lose weight, i.e., an equilibrium could not be established by manipulating stocking rate; (3) the heavy stocking rate will yield a higher gain per unit area of land than moderate or light, since higher gain per head at moderate and light stocking rates was insufficient to compensate for the smaller area per head at the heavy stocking rate; and (4) gain per head on heavily grazed pastures should generally be more variable than for moderate or light stocking rates.

Mott (1960) pointed out that it would be inappropriate to suggest actual values for the constant in the equation presented by

Harlan (1958) for the stocking rate-gain/animal relationship, except for specific sets of data, since the shape of the product-per-animal curve would differ for different ratios of feed requirements for maintenance to feed requirements for performance. The optimum grazing pressure concept then was submitted (Mott, 1960):

$$Y' = K - ab^{X'}$$

where

Y' = the ratio of product per animal to the product per animal at the optimum grazing pressure

X' = the ratio of stocking rate to the stocking rate at the optimum grazing pressure

and K, a, and b are constants.

Subsequently, a generalized curve was proposed for gain per unit land area of the form

$$Z' = X'Y'$$

where Z' is the ratio of gain per unit land area to the gain per unit land area at the optimum grazing pressure. The relationships mentioned above mean that if a pasture is stocked below the optimum rate, higher gain per animal will result, and at light stocking rate, stocking rate has very slight effect on gain per animal over a wide range. Stocking rates higher than the optimum will greatly affect performance per animal because feed supply is reduced and selectivity declines considerably to the point where all feed produced in the pasture is consumed for maintenance and gain per animal will be zero. Mott (1960) also suggested that the optimum stocking rate could only de defined as an optimum range and that this stocking rate is somewhat lower than that which will give maximum product per unit area.

Riewe (1961) reviewed several selected grazing studies across the United States to measure the relationship between stocking rate and liveweight gain. His relationship denotes that animal gain is increased as stocking rate is decreased. But a point is reached where further reduction in stocking rate cannot result in any further increment of animal gain. At this point, should further reduction in stocking rate result in forage becoming rank and advanced in maturity, it could decrease animal gain. Riewe (1961) also pointed out that the stocking rate at the point of no gain is approximately twice the stocking to produce the maximum gain per unit area of land.

Petersen et al. (1965) proposed a theoretical expression in which gain per animal is constant as stocking rate is increased to a "critical" point and beyond this point gain per head is inversely related to stocking rate. On the other hand, gain per unit area increases linearly as stocking rate is increased to the "critical point" and then decreases linearly with further increases in stocking rate. The critical point is defined as the stocking rate at which total forage consumed is exactly equal to the total grazable forage, providing all animals are grazing at maximum capacity. This concept, as pointed out by Matches (1970), is similar to the "animal potential" and "grassland potential" suggested by Ivins et al. (1958). For example, until stocking rate is increased to the "critical point," the grassland potential exceeds the animal potential. Cowlishaw (1969) elaborated on the theory developed by Petersen et al. (1965) by indicating that their conclusions on gain per animal apply only to an instantaneous situation because in practice the available forage is not of uniform composition, selection takes place, and therefore, the digestibility of the forage consumed declines with increases in stocking rate. Morover, the requirements for maintenance of the grazing animal also change as they grow and fatten. Mott (1973) reported a more elaborate version of the concept of optimum grazing pressure with the generalized curve, to represent a more realistic and practical situation. He reemphasized that the optimum grazing pressure must be considered as an optimum range and not as a "critical point" and that such an optimum relates only to animal output, but excludes optima for plant species in the pasture.

Jones and Sandland (1974) compiled the results of several grazing trials from both temperate and tropical regions to derive their relationship which was quite similar to that advocated by Mott (1960, 1973). Their results were expressed on a common basis by calculating the optimum stocking rate and relating ratios of gain to ratios of stocking rate relative to that at the optimum. They proposed a linear relationship between stocking rate and gain per animal in accordance with those found by Harlan (1958), Riewe (1961), and Cowlishaw (1969). The proposed equation was:

$$Yg = a - bX$$

where Yg is the gain per animal, X is the stocking rate, and a and b are constants. The relation between gain per unit area (Y_u) and stocking rate (X) would then be

$$Y_u = aX - bX^2$$

In accordance with the laws of differential equations, the authors indicated that the maximum gain per unit area occurs when $X=a/2b$.

Recently, Connolly (1976) issued some strong comments about the linear equations and their supposed "simple qualities" as presented by Jones and Sandland (1974) as well as earlier linear models. In his paper, Connolly examined the biases involved in the estimation of optimum stocking rate by Jones and Sandland (1974). He then proceeded to charge them with assuming linearity even in situations where the true relationship was quadratic and warned against the problems that could arise in the estimation of important parameters in grazing experiments from adopting their model. Connolly also provided experimental evidence involving five stocking rates where using within herd variation as error, the quadratic term was negative and significant at the 5% level of probability when gain was regressed on stocking rate and the square of the stocking rate.

Despite the fact that details of the exact equation remain unresolved, the weight of the above experimental evidence supports the contention that increases in stocking rates to the optimum range would result in substantial increases in animal production per unit area at the expense of individual animal production. If the optimum stocking rate under any set of conditions is established, stocking rates could be adjusted toward efficient production goals.

Stocking Rate Designs in Grazing Trials

The use of fixed or variable stocking rates provides a clear demarcation between the two major groups of stocking rate designs (Wheeler et al., 1973). The designs can be further subdivided according to the duration of the experiment and the method of selecting variable stocking rate. The designs are defined as follows:

Fixed Stocking Rate Experiments

The stocking rates are fixed at predetermined levels for at least 1 year.

Short-term, Fixed Stocking Rate Experiments

The stocking rates are fixed at predetermined levels for experiments of less than 1 year's duration.

Put-and-Take Experiments

The stocking rates are varied according to an uncontrolled but measurable criterion and the experimental duration is not defined.

Seasonally Altered Stocking Rate Experiments

The stocking rates are varied to predetermined levels during a year, while the experiment has a minimum of 1 year's duration.

The latter, in essence, is a seasonal put-and-take experiment and should be very useful in the wet-dry seasonal conditions of many countries in the world.

In the put-and-take (P & T) grazing, also known as the variable stocking procedure, the stocking rate is varied by the researcher as frequently as the availability of the forage requires. The traditional P & T method, in which stocking rate is intentionally varied to maintain a constant grazing pressure, was first described by Mott and Lucas (1952), and subsequently in more detail by Lucas (1962), Petersen and Lucas (1968) and Matches (1970).

Many advantages and a few disadvantages have been argued for the put-and-take, or variable stocking-rate-constant forage supply approach. It is beyond the purpose of this discussion to debate the relative merits of variable versus fixed stocking rates in essentially biological terms. A large quantity of literature already exists on this subject (Morley and Spedding, 1968; Wheeler, 1962; Willoughby, 1970; Matches, 1970; Wheeler et al., 1973; and Blaser et al., 1974). It is apparent from the discussion of the cited authors that both the fixed and variable stocking methods of conducting a grazing experiment have a place.

> The controversy over the validity of the two methods persists despite the statement by Mott (1960) that with variable stocking rate the frequency of adjustment "is dependent on local application of results" and the conclusion of Morley and Spedding (1968) that "stocking rates within a treatment should not be varied at different times unless such variation is related to a feasible practice in some actual or conceptual system." (Quoted from Wheeler et al., 1973, p. 301)

The choice between fixed and variable stocking could be based on the suggested criteria listed by Wheeler et al. (1973). Their suggested criteria were that the variable stocking method is the more appropriate choice where (1) the pattern of forage growth is markedly periodic; (2) it is not possible to maintain quality of forage if the forage is left uneaten; (3) maximum degree of flexibility available to accommodate forced or planned changes in animal number exists; (4) opportunity to modify animal response by management during trial is unlimited; (5) potential animal production or crop or total system can be only approximately predicted at the design stage; (6) marketable animal product is not necessarily dependent on the forage growth cycle; (7) the experimental result can be used later on a complex farm; (8) results are to be applied to farming practice extrapolated or after further study; (9) the degree of disturbance to ecosystem acceptable is substantial. The fixed stocking rate is recommended for the situations contrary to the above options. Wheeler et al. (1973, p. 301) stated,

> It does not follow that put-and-take, as a valuable experimental tool, cannot validly be used in development of grazing systems. Given consideration of the factors discussed, and an acceptance of the generalization that variable rates tend to be appropriate for the study of components of farm systems and fixed rates for the study of the systems *per se*, most of the controversy could be resolved.

It seems apparent that the put-and-take system is more appropriate when the plant-animal relationships are to be defined, a major goal in pasture research.

Evaluating Forages by Animal Performance

Research in forage evaluation has been usually in terms of forage production, utilization, and chemical analysis, and less frequently in terms of animal performance. Evidently, technical difficulties in studies with the grazing animal, high cost of this type of work, and occasional failure to obtain results that can be analyzed are the main factors limiting the use of animal performance trials.

Evaluation of pasture by animal response has the following advantages: (1) the results are directly applicable to the rancher; (2) the forage is harvested by grazing animals and not by some mechanical means; and (3) the results may be expressed directly in terms of individual animal performance and yield of animal product per unit of area (Mott and Lucas, 1952).

According to Mott (1959), there are two aspects of a grazing experiment. The first is concerned with estimating forage quality by measurement of the response of the grazing animal to the forage consumed. The second has as its objective the measurement of the number of animals which the pasture will carry when grazed at its optimum rate. The latter furnishes an estimate of the forage output of the pasture so in this sense is a measure of quantity. If the animal performance (quality aspects) is expressed as "product per animal per day" and the grazing rate (quantity aspect) as "animal days per unit area" and if all the animals are similar in rate of consumption and performance, then:

Product per animal per day x animal days per unit area = product per unit area.

Measuring Animal Performance

Animal performance reflects the amount and quality of forage consumed per animal and the animal quality and, thus, indirectly reflects the quality of available forage (Lucas, 1962). It has been described by several investigators as a function of the nutritive value and rate of intake, and has been expressed as a specific amount of product per animal. Time is usually defined on a daily or seasonal basis (Mott, 1960).

The performance of grazing animals may be measured in terms of the amount of body weight maintained and/or gained, or in terms of intake of digestible organic matter. Naturally, these responses will reflect the combined effects of the nutritive value per unit of weight of forage consumed and the amount of forage consumed (Reid, 1962). But, the final measure of the value of a pasture is its yield per unit area for the maintenance of animals, or for maintenance plus production (Harris, 1962). The yield per unit area may be expressed in terms of (1) yield of herbage dry matter, energy or nutrients, (2) the maintenance, or maintenance plus production, responses of animals expressed in calories or other nutritional units, and (3) animal grazing days per unit area for a certain physiological function (Harris, 1962). There are several alternative methods available to the investigator to measure animal performance in grazing experiments.

Computing Yield of Animal Products from Animal Performance

Three methods for computing yield of animal products per unit area of land have been proposed by Mott and Lucas (1952). The three methods differ mainly with respect to which animals are used to evaluate average daily performance and animal days.

Method I involves the computation of animal product per unit area on the basis of all animals. The units of measure computed are:

1. Total product (e.g., meat) from all animals per unit area
2. Total animal days per unit area
3. Average daily performance of all animals

Product per unit area is then calculated as:

Animal days per unit area x average daily performance = product per unit area.

Method II is generally used for computation involving the "put-and-take" method of pasture experimentation. The following units of measure are computed:

1. Animal days computed from all animals on the pasture
2. Average daily performance computed from only those animals remaining on the pastures during that entire experimental period. These are called "tester animals"

Yield per unit area is then obtained from the expressions:

> *Animal days per unit area x average daily performance of tester animals = product per unit area.*

It is obvious that if a constant number of animals (all tester) is used, then observed product per unit area (method I) will be identical with that obtained by the above expression. If, however, animal numbers are varied through the season and daily performance is computed only from the testers, the computed product per unit area will not be identical with that observed. The validity of method II is dependent upon all animals having similar consumption rates and fairly uniform consumption throughout the experiment period.

Method III is also used for calculation involving the "put-and-take" method. This method involves the conversion of observed measurements to total digestible nutrients (TDN) or some other feed units. Conversion factors on a TDN basis are given by Petersen and Lucas (1968). The following units of measure are computed:

1. The TDN consumed from the pasture by all animals. This is computed from the nutrient requirements for liveweight increase and/or other product, for maintenance, and for energy expended in grazing.
2. The daily TDN consumption of the average tester animal.
3. The average daily performance of the average tester.

Animal days are then computed in terms of the average tester as follows:

$$\frac{\textit{TDN yield per unit area}}{\textit{Daily TDN consumption of average tester}} = \textit{tester animal days}$$

Yield per unit area in terms of the average tester is obtained by the expression:

Tester animal days x daily performance of

average tester = tester product per unit area.

Method III has certain advantages: First, the put-and-take tester animals may be quite different, and second, several kinds of testers may be used on the same experiment allowing the estimation of production per unit area in terms of more than one type of tester.

Factors Affecting Animal Performance

In evaluating forage quality in terms of animal performance, differences in animal potential and limited availability of forage must be avoided. Therefore, assuming that animal potential does not change and forage availability is not limiting, differences in forage quality can be attributed to changes in forage nutritive value and forage consumption (Mott and Moore, 1970).

Forage nutritive value, as described by Mott (1959), Mott and Moore (1970) and Lucas and Mott (1962), consists of the chemical composition, digestibility of the components and the nature of the digested fraction. Hutton (1971) defined the nutritive value of pasture by its ability to produce meat, wool or milk when there is sufficient feed and the animal's potential for production has not been reached. Where a deficiency of protein or minerals occurs, production will be reduced through a decreased voluntary intake (Hutton, 1971; Evans, 1970; Minson, 1972). Burton (1970) pointed out that improving the digestibility and intake of a forage will increase daily animal production even though forage dry matter yield may not be altered. Carrying capacity may decrease, however.

The species and age of the plant and the season of the year will affect animal performance. Oliver (1972) pointed out that as the summer progresses there is a natural tendency for the plants to mature, consequently, a decrease in the quality and amount of forage produced will occur. This results in a decrease in the daily weight gains of grazing animals. Management practices that would tend to keep the plants in a young, immature state of growth would delay the natural plant maturity and cause the growth of more desirable forage.

Animal days and output per unit area are very dependent upon factors such as type and physiological condition of the animal and their interaction with intensity of grazing (Mott & Lucas, 1952). They stated that expressing the yield in terms of some feed unit has greater generalization value and, if proper conversion factors are available, the results are fairly independent of the types and physiological status of the animals. They stated further that grazing pressure or intensity of grazing also appears to have less effect on the feed unit than on other units of measure unless the rate of stocking is substantially below the carrying capacity.

Another important factor affecting animal performance and animal production per unit area is the stocking rate. At very low stocking rates, product per animal is high and generally not influenced by the stocking rate (Thurbon, Cowan & Chopping, 1971). This high animal yield is probably due to the greater opportunity for selective grazing resulting in a diet having a higher nutritive value (Mott, 1960). As the grazing pressure is increased by increasing the stocking rate, the animal's energy intake declines with the result that product per animal decreases. If this decrease is small, product per unit area is increased with the increased grazing pressure. Further increases in stocking rate will reduce production per animal to the extent that yields per unit area are decreased (Thurbon et al., 1971). When the stocking rate is increased to the point that all the feed produced on the pasture is used for the maintenance requirements of the animals, then product per animal will be nil (Mott, 1960). Therefore, it is evident that grazing management must be a compromise between rate of gain per animal and rate of gain per unit area (Blaser, Harland & Love, 1962; Blaser et al., 1960).

Finally, the use of animal liveweight as a base for estimating forage quality may be limited by the probably occurrence of marked variations in body condition and gastrointestinal fill (Hodgson, Taylor & Lonsdale, 1971). Therefore, it is advisable to allow time for the animals to become accustomed to the forage and to recover from the effects of previous treatment and handling (Joint Committee Report, 1952). Furthermore, weight variations due to water fill can be minimized in beef cattle and sheep by weighing them after they have been on pasture but excluded from water for the previous 12 hours, preferably overnight, or by weighing them after an overnight shrink without feed and water. Also, weighing just after daylight on each weigh day is easier on the animals and holds variation to a minimum.

Measurement of Botanical Composition

Although results of grazing trials are evaluated in terms of animal production, forage measurements constitute an essential and primary necessity if the pasture-animal system is to be understood adequately.

That pastures are dynamic systems is a fact well known and accepted. Several factors are acting upon forage species growing either alone or in a mixture. Soil fertility, environmental conditions, and grazing management are probably the most important ones. Seasonal effects may alter botanical composition (Mears, 1973; Bryan & Evans, 1973).

A full interpretation of a grazing experiment requires an accurate knowledge of the botanical composition of the pasture and the way this composition changes between treatments and with time. In grass-legume pastures, the proportion of legume is crucial to the N balance system. Animal production often can be related to botanical composition, particularly to legume content (Norman, 1970; Evans, 1970; 't Mannetje, 1974). Dry matter and botanical composition must be measured over a number of years to gain an understanding of the changes in the sward.

Measurements of botanical composition may be in terms of the yield of the species components, the frequency of occurrence of different species, the number of plants present or the area covered by different species.

Floristic composition must be qualified as being on the basis of weight, frequeny, cover and so on.

Weight. Where the productivity of the vegetation is being studied, the composition on a dry weight basis may be a useful determination. Because of the tedious nature of cutting and separating samples by hand, many estimation, ranking or indirect methods have been developed (Tothill, 1978) in attempts to overcome these problems and have been used to varying degrees of success. One that has won a considerably following for tropical studies is the dry-weight-rank method of 't Mannetje and Haydock (1963) for estimating relative species composition. Non-destructive methods of pasture measurements (also called indirect methods by Shaw et al., 1976) are probably the most appropriate to estimate botanical composition under the conditions of grazing trials.

Cover. Cover is a measure of the proportion of ground or area covered by the whole vegetation, or by individual species, as measured by the perpendicular projection of their aerial parts onto the ground, and usually is expressed as a percentage. Basal area, which is the cover attributed to the basal rooted portions of plants, may be measured. Basal area or cover measures provide a useful basis for following colonization or change in the basic composition of the vegetation. Bare ground, or the absence of cover, may also be an important criterion of the stability of the vegetation (Coaldrake et al., 1976). Cover is usually measured by means of point samples, line intercepts or estimations.

Basal area or cover is an especially important characteristic because it measures long-term effects of climatic and soil conditions and grazing.

The point method defines botanical composition in terms of plant cover which may or may not be accurate. The point method is an accepted method for determining botanical composition, particularly when reinforced by weight analysis (double sampling).

The point analysis method has proven to be rapid and consistent once the observer has been trained in its use and limitations. It requires no laboratory analysis (which is a considerable savings in time) and it may be replicated many times more in a given period of time than other methods.

Measurement of Forage Quality

It is well accepted that the output per animal is a function of the intake of digestible nutrients (Mott & Moore, 1970; Burton, 1970; Van Soest, 1973), and it is within this context that digestibility is recognized as an important measure of forage quality for ruminants.

Digestibility. Mott (1973) indicated that the two-stage *in vitro* digestion technique proposed by Tilley and Terry (1963) or its modification such as that by Moore et al. (1972) is presently the most widely accepted procedure being used routinely. Of course, one of the most important advantages of the *in vitro* over the *in vivo* digestion technique is the fact that it is less time consuming, much less forage sample material is necessary, and a greater number of forages can be studied in a short time (Mott, 1973). However, forage sampling for predicting quality through *in vitro* procedures must be done in such a way as to approximate as near as possible the diet of the grazing animal.

Moore and Mott (1973) presented selected data where maximum dry matter or organic matter digestibility exceeded 65% in most cases and frequently was higher than 80% in temperate grasses while, in tropical grasses, those values were seldom higher than 65% and never greater than 80%. In this respect, Hamilton et al. (1970) suggested that, in terms of DM, OM, or energy, a digestibility of 65% in a tropical grass should allow adequate intake of digestible energy for dairy cattle.

Seasonal effects may alter pasture quality (Evans, 1969; Minson and McLeod, 1970).

French (1941) found that the dry matter digestibility coefficient of several species ranged between 51.1 and 72.8% depending on stage of growth. Marshall and Long (1967) indicated that the dry matter digestibility coefficient of some East African grass hays varied between 45.6 and 70.6%, depending on the species. Both reports were based on digestibility trials.

Smith (1962) indicated that the digestibility of organic matter in a *Hyparrhenia* veld in Africa declined from 50 to 38% as the grass matured and that fertilization increased digestibility by 10%. Jardim (1953) reported from Brazil that the digestibility of jaraguagrass decreased from 56.6% at a young stage to 42.7% after flowering. However, Miller et. al. (1963) found that the digestibility of jaraguagrass in Nigeria determined at preflowering stage, in the middle of the rainy season, was only 39.6%. This value was lower than that of any other grass studied.

Crude protein. The quantity of forage eaten is primarily controlled by the extent and rate of digestion within the rumen (Balch & Campling, 1962). However, when a feed contains insufficient N, voluntary intake is reduced below that limited by rumen distention (Minson, 1967).

The critical level of crude protein required in a pasture before intake is reduced by N deficiency has been estimated at between 6.0 and 8.5% (Blaxter and Wilson, 1963; Milford and Minson, 1965; Minson and Milford, 1967). Values below this level have often been found in mature tropical grasses (Butterworth, 1967).

The evidence suggests that as crude protein content declines, digestibility also declines and both of these nutritive qualities are negatively correlated with increase in maturity or with a downward movement into the canopy of the pasture (Minson et al., 1964; Wilkinson et al., 1970).

The application of N fertilizer to the sward, the inclusion of legumes, and the feeding of N supplements are obvious ways of overcoming any deficiency in N which may exist.

Milford and Minson (1966) observed that a marked decline in intake of tropical grasses occurred when the crude protein content fell below approximately 7%, and that above this level it has little effect on intake. Their conclusion was that the lack of crude protein for the rumen flora may have caused a low-energy intake which was responsible for the low feeding values of many mature tropical grasses. This low crude protein content also may have influence on the *in vitro* digestion by depriving the rumen fluid bacteria of some of their N requirements (Waldo, 1968).

Jardim et al. (1966) reported that the crude protein content of jaraguagrass in Brazil was as high as 11.8% at the end of the rainy season. French and Chaparro (1960) found that the crude protein content of jaraguagrass in Venezuela varied from 1.4 to 7.3% during the dry season.

Pedreira et al. (1966) found that the crude protein of jaraguagrass in Brazil increased from 7.7 to 9.4% when fertilized with N, P, K and micronutrients after application of lime. Blue[1] reported that the crude protein of jaraguagrass in the hot savanna of Costa Rica increased to 9.5% during the rainy season with application of 210 kg of N/ha and to 9.4% when fertilized with 120 kg of N/ha at the end of the dry season. However, the effect of N fertilization on crude protein concentrations of the forage did not last beyond the middle of the dry season.

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[1] Blue, W. G., 1960. Fertilization experiments with grass pastures in Costa Rica. Final report of assignment to Costa Rica under the University of Florida/STICA contract. University of Florida, Gainesville, Florida.

The protein concentrations of tropical grasses follow a marked seasonal pattern tending to decrease during the dry season regardless of N fertilization. Brendon and Horrell (1961) indicated that all the grasses studied in Uganda showed a considerable decrease in the protein content from the beginning of the rains to the end of the dry season. Lansbury et al. (1965) found that the protein concentrations of grass in Ghana fell from 13.0% after the first rains to 3.4% during the dry season.

Andrade et al. (1964) working with jaraguagrass under field conditions in the savanna region of Costa Rica found that protein declined in the forage during the dry season. They indicated that since there was no rain to have leached protein from the leaves and since no appreciable loss of leaves from the plant took place, N must have been translocated to the roots under the unfavorable growth conditions of soil moisture stress. However, they did not present root data to support their suggestion of N translocation.

Measurement of Mineral Composition

The chemical composition of a pasture is a valuable indicator of the quality of the pasture in terms of protein and mineral composition and a means of explaining animal production over the seasons of the year. The large fluctuations in chemical composition of pasture in areas with pronounced wet and dry seasons make it necessary for samples to be taken frequently throughout the year if meaningful results for the interpretation of animal weight changes are being sought. Such samples may be used to assess plant nutrient status, and if the samples are representative of what the animals are eating, they may indicate the likelihood of deficiencies affecting animals.

Calcium and Phosphorus. Calcium deficiency in forages for grazing ruminants is rare and has not been reported in Brazil. For grazing livestock the most prevalent mineral deficiency throughout the world is lack of P with reports of deficiencies in at least 38 tropical countries (Fick et al., 1976).

Several workers in Brazil reported P deficiencies, principally during the dry season (Gallo et al., 1974; Haag et al., 1967; Prospero and Peixoto, 1972; Teixeira et al., 1971; Jardim et al., 1962a; Jardim et al., 1962b). All of them reported adequate levels of calcium in both dry and wet seasons.

Veiga (1976) summarized the P values from 1,030 grass samples collected from a majority of the Brazilian states during different months and different stages of maturity. Results were as follows: 76% of the grasses contained less than 0.20% P; 51% contained less than 0.15% P; and 20% contained less than 0.10% P. The majority of the forages were guineagrass, jaraguagrass, molassesgrass and pangolagrass.

Blue and Tergas (1969) reported that forage P decreased during the dry season and that Ca was less affected. They also suggested that nutrient losses from the forage were probably due to translocation to the root system and then to the soil.

Sousa (1978) found that forage P was deficient for grazing cattle and ranged from 0.07 to 0.18% in grass samples from six ranches in northern Mato Grosso, Brazil.

The NRC (1976) recommendation for steers weighing 450 kg is 0.18% of Ca and 0.18% of P in the dry matter consumed.

Magnesium. Occasional Mg deficiencies have been noted, especially on sandy soils or soils with low levels of Mg in relation to K and possibly Ca. França et al. (1973) reported that the importance of liming for legumes in cerrado soils of the state of Minas Gerais is due more to the increased availability of Mg to the Rhizobium. Magnesium is involved in the digestion of starch and cellulose.

In São Paulo, Andreasi et al. (1968) studied the mineral composition of tropical grasses and reported that the highest Mg concentrations for jaraguagrass were 0.36% in the dry season and 0.26% in the wet season. Blue and Tergas (1969) reported that Mg was apparently nutritionally adequate for cattle in the forages studied in Costa Rica. Gallo et al. (1974) studied tropical forages and indicated that the Mg levels of legumes were higher than grasses and that a Mg deficiency was not found in any forages analyzed.

The NRC (1976) requirements of Mg for growing and finishing steers is 0.04 to 0.10% of dry matter intake.

Potassium. In Brazil, Gomide et al. (1969) studied the mineral compositions of six grasses and reported that the average K content at 4 weeks was 1.42% versus 0.30% at 36 weeks of age. These workers noted that a low forage K may be a critical factor in the poor performance of cattle during the dry season. Forages containing low levels of K have been reported in Venezuela (French and Chaparro, 1960).

Sousa (1978) found that the forage K content was adequate to meet the requirements for grazing beef cattle in the state of Mato Grosso, Brazil.

The NRC (1976) requirement of K for growing and finishing steers is 0.60 to 0.80% of dry matter intake.

Manganese. Manganese deficiency is seldom encountered in ruminants. Manganese deficiency in beef cattle results in delayed estrus and conception, and calves born with neonatal skeletal abnormalities (Rojas et al., 1965).

Andreasi et al. (1968) found that the Mn content of guineagrass was higher than of jaraguagrass. The highest values for Mn were found in the dry season.

Gomide et al. (1969) indicated that N fertilization increased the Mn content of the grasses an average of 41 ppm. Sousa (1978), found the forage Mn levels in the state of Mato Grosso, Brazil, were sufficient to meet the requirements of grazing cattle. The NRC (1976) reported a Mn requirement for growing and finishing steers between 1 and 10 ppm. The possible toxic level is 150 ppm.

Zinc. Until recently, Zn deficiency in cattle was thought unlikely under grazing conditions. In recent years Zn deficiency in grazing animals has been reported in several countries when dietary Zn was less than 40 ppm (McDowell et al., 1976). Legg and Sears (1960) demonstrated a parakeratosis skin disorder of cattle in Guyana which were consuming forage containing 18 to 42 ppm Zn. Andreasi et al. (1969) in Brazil reported that Zn levels were higher during the dry season than in the wet season, independent of the type of forage and type of soil. Guineagrass showed 60 and 37 ppm of Zn for the dry and wet seasons, respectively, while comparable values for jaraguagrass were 69 and 36 ppm.

In São Paulo, Gallo et al. (1974) reported no differences in Zn concentration between grasses and legumes. Zinc levels in herbage were lower than the nutritional needs of the animals.

Sousa (1978) found in grasses from northern Mato Grosso, Brazil, forage Zn levels that ranged from 19 (deficient) to 39 ppm (adequate).

The NRC (1976) Zn requirement for growing and finishing steers is 20 to 30 ppm.

Copper and molybdenum. The lack of Cu is probably the most severe mineral limitation to grazing cattle in Latin America, with the exception of P and possibly Co. Copper deficiency is induced by low concentration of Cu in forages. However, "conditioned" Cu deficiency also occurs where normal Cu concentrations in forages are inadequate due to interrelationships with Mo, sulfate and other factors (Russell & Duncan, 1956).

In an experiment carried out in central Brazil, Teixeira et al. (1971) found Cu levels in grasses between 2.50 and 3.03 ppm which showed Cu deficiency in this area. Gallo et al. (1974) studied forages from São Paulo and reported that the mean values for Mo were lower in legumes than in grasses, whereas legumes contained more Cu than grasses. They also reported copper concentrations inadequate to meet cattle requirements in most of the forage samples.

Sousa (1978), analyzing forage samples collected from six ranches in northern Mato Grosso, Brazil, indicated that Cu levels ranged from 2.7 (deficient) to 4.4 ppm (adequate). He also found that the forage Mo levels were 9.2 ppm (toxic level) on one farm and ranged from 1.4 to 0.1 ppm (low level) on the other farms.

The NRC (1976) listed Cu requirement for growing and finishing steers as 4 ppm. The cattle requirement for Mo is 0.01 ppm or less (NRC, 1976) and toxicity is 6 ppm (NRC, 1978), when diets contain low Cu concentrations.

Cobalt. Cobalt has not been demonstrated as essential for the growth of higher plants. However, Reisenhauer (1960) indicated that Co plays an important role in N fixation by the bacteria. Legumes contain higher levels of Co than grasses (Robertson, 1971). Gallo et al. (1974), Jardim et al. (1962b), Correa (1957), Magalhães (1949) and Pereira (1971) indicated Co forage concentrations inadequate to meet cattle requirements in Brazil.

Sousa (1978) reported that forages from northern Mato Grosso had Co mean levels in the range of 0.04 (deficient) to 0.14 ppm (adequate).

The NRC (1976) Co requirement for growing and finishing steers is between 0.05 and 0.10 ppm.

Measurement of Economic Response

Agronomists and animal scientists have often been accused by economists of being too concerned with biologically optimum production and not enough with economically optimum production. Experiments have sought to maximize production rather than profit and these do not necessarily occur at the same levels of input, whether of fertilizers or capital. At levels of maximum production the last unit of input may cost more than the income obtained from the resulting output. In grazing experiments in particular, there has been an increasing awareness of the need for economic appraisal.

The experimental data on pasture establishment, fertilizer use, stocking rate and animal production form a basis for the inputs and outputs in an economic analysis. Economic interpretation always requires comparisons with alternative forms of production. Where the grazing experiment is aimed at developing animal production systems to replace existing ones, the latter obviously must be included in the comparison. The main criterion would then be to judge profitability on the basis of the returns to extra investments necessary for the new system, over and above those used in the existing system.

Cost/profit relations are often very sensitive to price fluctuations, as was shown by Michell et al. (1972), Firth et al. (1974), and Miller et al. (1970). Alternative production systems should, therefore, be analyzed at a range of price levels for both inputs and outputs, and relationships should be derived so that any changes in price or production can be interpreted without having to reanalyze the results.

Any attempt to discuss the optimal methods of pasture improvement, in the sense of describing the techniques that are most efficent and profitable, is largely meaningless except in the very limited sense of a single set of price relationships.

For tropical beef production, there is little economic evidence yet available on the productivity of land and capital associated with different levels of stocking and different levels of pasture improvement. Comparisons of beef production from grass-legume pastures with N-fertilized grass pastures from several tropical regions have been reviewed by Nuthal and Whiteman (1972), Norman (1974), and Stobbs (1975). The general conclusion from these reviews was that N-fertilized grass pastures seemed likely to be profitable only at heavy rates of application and at low fertilizer prices.

CHAPTER III

MATERIALS AND METHODS

Experimental Sites: General Description of the Experiments

The data presented in this investigation are from grazing trials conducted at private ranches in central Brazil. Description of the cerrado region in central Brazil has been given in Chapter II. Grazing experiments were designed to measure the effects of pasture attributes on beef production.

Grazing Trial No. 1

Location and climatic description. This grazing experiment was located on Fazenda Xangrilá, in the Luz district of the state of Minas Gerais (lat. 19° 50' 20" S; long. 45° 50' 40" W; alt. 680 m). The average minimum and maximum temperatures are approximately 16 and 30° C, respectively, and the average annual precipitation at trial site is 1,200 mm. About 80% of the yearly rainfall occurs in the warm season. The period from December to March is when most of the rain falls, with rains of high intensity. In contrast, July and August often receive no rainfall.

A period of rapid liveweight gain by cattle is to be expected from mid-October to April or May (hereafter referred to as the wet season) with liveweight loss or reduced gain (including a transition period of one month after the first rain) from mid-April or May to mid-October (hereafter referred to as the dry season).

The soils are classified as Red Yellow Latosol, with a soil reaction of pH 5.0 and low fertility. The area in which the experiment was located was cleared of the original cerrado vegetation in 1974 and was subjected to the following treatments.

Treatments. 1. Mixed pasture of guineagrass *Panicum maximum* cv 'Guiné' with Siratro *Macroptilium atropurpureum*, perennial soybean *Glycine wightii* Willd. cv. Tinaroo and Stylo *Stylosanthes guianensis* (Aubl.) Swartz cv Schofield (area 14.8 ha).

2. Pure stand of guineagrass *Panicum maximum* cv 'Guiné', fertilized with 100 kg of N/ha (area 10.6 ha).

'Guiné' grass is a local cultivar of *Panicum maximum* and is a medium size type and poorly understood taxonomically and phytogenetically.

Design and field plan. Each treatment was replicated three times, making a total of six pastures. The pastures were arranged in a completely random design.

Fertilizer application. Soil samples collected in the field were analyzed in the laboratory for physical and chemical properties.

All pastures received a basal fertilization for pasture establishment. Three months before the fertilization. 2.5 tons of dolomitic limestone/ha were applied. The P source was Termofosfato (Araxá rock phosphate heated with $MgSiO_3$ containing 19% total P_2O_5 of which 18% P_2O_5 is soluble in citric acid), and was applied at the rate of 580 kg/ha. This Termofosfato fertilizer includes in its composition the following elements: MgO, 18%; CaO, 28%; Zn, 16%; and traces of Mo, Cu, Mn, Co, Fe, and SiO_2. Two years after the pastures were established, a maintenance fertilizer dressing was applied which included simple superphosphate at 30 kg of P_2O_5 kg/ha and potassium chloride at 30 kg of K_2O/ha.

For the grass plus N treatment, a total of 100 kg of N/ha as ammonium sulphate was applied during the first grazing season (50 kg of N/ha in the spring and the same in the autumn).

In early December 1974, a mixture of 'Guiné' grass, Siratro, perennial soybean and stylo was sown at the rates of 13.5 kg/ha for the grass and at 2.0 kg/ha for each of the legumes, respectively. Each legume was inoculated with the appropriate strain of Rhizobium and pelleted.

The pasture layout is presented in Fig. 4, and rainfall pattern at trial site, for the experimental period reported here is shown in Table A-1.

About 120 days after planting, over a period of about 20 days, all pastures were lightly mob grazed by the steers which were to be used as experimental animals. The experimental period started on 3 October 1975 and continued for 11 consecutive months.

Animals. The animals used in the experiment were Gir x Holstein steers. At the beginning of the experiment the steers had an average age of 30 months, with average weight of 308 kg. During the course of the experiment, when steers reached marketable condition, they were sold for slaughter and replaced by steers of the same starting age. This procedure would allow, if necessary, measurement of treatment effects on rates of turnoff. Thus, the trial was subdivided in "phases" within the wet and dry seasons. Six hundred and sixty-four steers were involved in the trial, for the period October 1975 to August 1976.

Grazing pressure. The "put-and-take" method was followed to obtain the near optimum grazing pressure for the pastures in the treatment.

Computational procedure. The weights obtained from the "tester" animals were used to compute the average daily gain considered to estimate the quality of the forage produced.

The procedure used was the following:

$$\text{Tester average daily gain for the period} = \frac{\text{Total gain of tester steers}}{\text{Total tester steer days}}$$

In order to compute the product per hectare estimating the quantity of herbage produced, all the animals grazing the pastures were considered.

$$\text{Output per hectare for the period} = \text{Tester average daily gain for that period} \times \text{total number of tester steer days}$$

The gain per animal per treatment was obtained by the following relation:

$$\text{Gain per tester animal} = \text{Tester average daily gain} \times \text{number of days in the period}$$

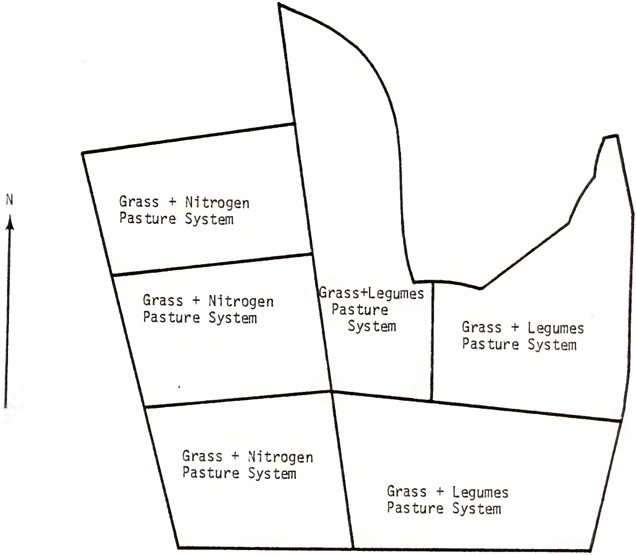

Fig. 4. Layout of experimental pastures in grazing trial no. 1.

Calculations were also made for the following:

$$\text{Steers per hectare per day} = \frac{\text{Total steer days/No. days in the period}}{\text{Size of pasture (ha)}}$$

$$\text{Tester animal days} = \frac{\text{TDN yield per ha}}{\text{Daily TDN consumption of average tester}}$$

The kilograms of TDN per hectare is measured in terms of total TDN estimated to have been required to maintain all animals (testers plus put-and-take) and to support their producton.

$$\text{Feed efficiency} = \frac{\text{Kilograms TDN yield/ha}}{\text{Kilograms gain/ha}}$$

Calculations also were made for average daily gain, output per hectare and steers per hectare per day for combinations of seasons. Measurements of botanical composition were performed at short intervals, sometimes every month, during both seasons. Subsamples of plucked forage were used for quality analysis in the laboratory.

Grazing Trial No. 2

Location and climatic description. This grazing experiment was located on Fazenda Castelo, in the Rio Verde district of the state of Goiás (lat. 16° 40' S; long. 49° 15' W; alt. 738 m). The mean annual rainfall in the period of this investigation was 1,330 mm in 1976 and 1,737 in 1977. Rainfall data measured in this region for 26 years averaged 1,491 mm.

The climate is characterized by about 5 months of cool, dry winter weather from May-June to October and a warm, wet summer season from November to May. Occasional light frosts are experienced between

July and August, and the rainfall pattern at trial site, for the experimental period reported here, is shown in Table A-2.

The soils are classified as Red Yellow Latosol, with a soil pH of 5.7 and medium fertility. The area in which the experiment was located was cleared from the original "cerradão" vegetation planted to jaraguagrass pasture, depleted after some years of utilization.

Treatments. The land was plowed in 1974 and the following treatments were imposed:

1. Mixed pasture of green panic *Panicum maximum* var. *trichoglume*, with *Centrosema pubescens* and *Stylosanthes guianensis* cv Endeavor
2. Unfertilized jaraguagrass *Hyparrhenia rufa*

A completely random design was used. Animals grazed the two replicates continously as is the practice on ranches in the region. The pasture layout is presented in Fig. 5.

Fertilization. The soil samples collected in the field were analyzed in the laboratory for physical and chemical properties.

All pastures received a basal fertilization for pasture establishment, which contained the following nutrients essential for plant growth: 80 kg of P_2O_5/ha and 30 kg of K_2O/ha. The P source was simple superphosphate. Potassium was applied in the form of potassium chloride.

In December 1974, a mixture of green panic, centro and stylo was sown and the rates (kg/ha) were: *P. maximum* var. *trichoglume*, 7.0; *Centrosema pubescens*, 3.5; and *Stylosanthes guianensis*, 2.5. Before sowing, each legume was inoculated with the appropriate strain of *Rhizobium* and pelleted.

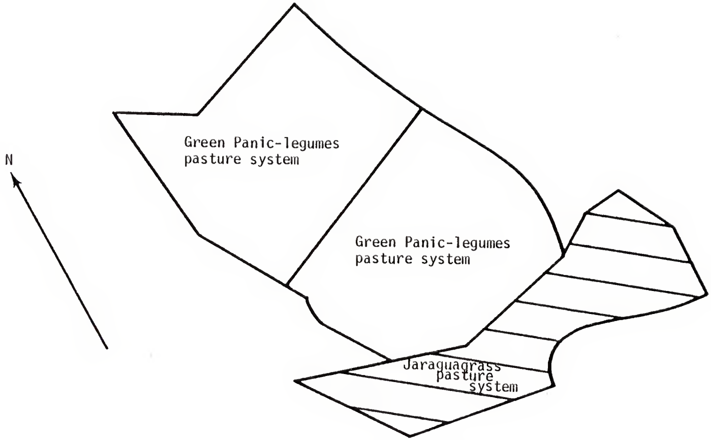
N
Green Panic-legumes pasture system
Green Panic-legumes pasture system
Jaraguagrass pasture system

Fig. 5. Outline of experimental pastures in grazing trial no. 2.

The pastures were considered completely established, after attaining a good stand following a natural re-seeding of the green panic. The grazing trial study was then started at the onset of the rainy season.

Cattle were weighed every 4 weeks in 1975-1976; an exception was during the dry season of 1976, when a strong incidence of foot-and-mouth disease affected the experimental steers. Therefore, no weights were taken during the period of the disease to avoid extra stress on the stock. In 1977, at the owner's request, steers were weighed at 56-day intervals.

Animals. The animals used in the experiment were Nellore and/or Nellore x Chianina crossbred steers. For the grazing period 1975/1976, the "tester" steers were 18 to 20 months of age and the "put-and-take" animals were 24 to 30 months old. For the second grazing period (1977-1978), all the steers were 18 to 24 months of age and again Nellore and/or Nellore x Chianina stock was used. The average initial weight was 300 kg.

Computational procedures. The same procedure as used in grazing trial no. 1 was followed here to compute average daily gain, gain per hectare, gain per animal, and steers per hectare per day.

Measurements of botanical composition were also performed during the duration of the trial. Subsamples of plucked forage were used for quality analysis in the laboratory.

The Experimental Animals and Grazing Management for the Grazing Trials

Steers were ranked on liveweights and divided among pastures at random, according to weight classes. Cattle were weighed every 4 weeks and the initial and final weights calculated from liveweights on two consecutive days at the beginning and end of experimental grazing. On all occasions steers were confined for approximately 16 hours without feed or water before weighing.

A variable stocking rate procedure was followed to obtain the near optimum grazing pressure for all pasture treatments (see page 63). It was thought that each pasture would produce enough forage during the grazing season to maintain the tester steers allotted to each pasture. Additional animals were used to maintain the grazing pressure near optimum during periods when forage was in excess of that needed by the tester animals. When steers were added or removed from the pastures, the same overnight fasting procedure was followed. All weights were taken at about 2 hours after sunrise.

Water was always available in each pasture and a complete mineral mixture including trace minerals and salt, was fed free choice.

All the experimental animals were dosed strategically during the dry period with Tetramisole (7.5 mg/kg LW) against gastrointestinal nematodes. Vaccinations against foot-and-mouth disease were given every 4 months.

Continuous grazing on a year-round basis was the management system used as is the practice for most the ranches in the region. The experimental animals were Zebu steers or cross-bred (Bos indicus x Bos taurus), steers supplied by the ranch.

Soil Analyses

Soil samples from the top 0 to 15 cm were taken before plowing and again during the course of the experiments. They were air dried and analyzed at the laboratory at the National Research Center for Corn and Sorghum, Sete Lagoas, Minas Gerais.

Phosphorus and K were extracted with the double-acid procedure (0.05 N HCl + 0.025 N H_2SO_4), by stirring a 1:5 soil-solution mixture for 5 minutes and then filtering. Extractable P was determined by colorimetry on a phosphomolybdate complex using ascorbic acid as reductant. Extractable K was determined by flame photometry. Exchangeable Al, Ca and Mg were extracted with 1 N KCl, by using 5 minutes of stirring and 1:10 soil-solution ratio. Exchangeable Al was determined by titration with 0.01 N NaOH using phenolphthalein as an indicator. Exchangeable Ca and Mg were determined by atomic absorption. The pH values were determined in 1:2 soil: H_2O ratio. Particle-size distribution was also determined.

Pasture Sampling

A modified line point method (previously described by Heady et al., 1959) was employed in this study for percentage species composition on a basis of ground cover.

In this line-point method, a pointed steel pin was used along with a 20-meter tape or knotted rope, stretched tightly as near the ground as possible. In this system, basal contacts of vegetation were recorded at every meter as the pin was projected downward touching the tape (or rope) along its full length. A plant is hit when the point of the pin touches its base. Hits for each species were recorded and results were expressed in terms of the percentage of hits per 100 points. If at ground level, the point hits bare ground rather than vegetation, bare ground is recorded, even though aerial contacts have been recorded for the point in its projection through the overlaying vegetation.

No attempt was made to choose the location of a particular line within a pasture, except to stop for each new sampling unit at a distance of 50 paces from the last point sampled. In every new line the observers started the recording of plant hits where the 50th pace fell without regard to soil condition or to vegetation cover. By doing so, sampling lines were located at random in the pasture, eliminating personal bias in selecting the location of the sample areas.

Along with the line-point method, the measurement of green matter (cutting quadrats) using hand separation provided the basis for the estimation of botanical composition. Measurements of botanical composition were performed at short intervals, sometimes every month, during both seasons. Forage samples from about one-twentieth of the pastures were collected, during the sampling times, but it was impossible to measure herbage yields accurately. In order to obtain independence of variance and mean, it was necessary to transform the percentage composition data to arcsin $\sqrt{(\text{percentage})}$ prior to statistical analysis.

Forage Analyses

Pasture samples were hand plucked, dried at 70° C, and ground in a stainless steel intermediate Wiley mill to pass a 1-mm screen. Forage samples from grazing trial no. 1 were prepared and analyzed in the laboratory of the Veterinary College, Universidade de Minas Gerais, Belo Horizonte. Forage samples from grazing trial no. 2 were analyzed at the Soils and Forage Laboratory of the University of Florida.

Two grams of oven-dry material were ashed in a muffle furnace at 450° C for 4 hours. The ash was cooled before adding 20 ml of 5N HCl. Solutions were evaporated to dryness on a hot plate to dehydrate silica. Residues were redissolved in 2.5 ml of 5N HCl, brought to a volume of approximately 20 ml with distilled water, and heated to boiling. The solutions were filtered through Whatman no. 41 filter paper into 50-ml volumetric flasks and made to volume with distilled water. Phosphorus was determined by the colorimetric procedure (aminonaphtholsulfonic acid-reduced molybdophosphoric blue method) outlined by Fiske and Subbarow (1925). Calcium, Mg, K, Zn, and Cu were determined by atomic absorption spectrophotometry (Perkin-Elmer 603). Cobalt and Mo were determined using an atomic spectrophotometer (Perkin-Elmer 506) equipped with a graphite furnace model HGA 2000, and D_2 corrector.

Crude protein (CP) was determined using the procedure described by Moore and Kelly (1970). Percentage CP was obtained by multiplying the percentage total N by 6.25.

In vitro organic matter digestibility (IVOMD) was determined by the procedure of Tilley and Terry (1963), modified by Moore and Mott (1974). It consists of fermentation by rumen microorganisms followed by acid-pepsin digestion. The undigested residue was weighed after being recovered with glass wool filtration. Digestion of organic matter was determined, rather than dry matter, to avoid the error which might have been introduced by sand contamination of the sample (Moore et al., 1972).

CHAPTER IV

RESULTS AND DISCUSSION

A project which had as its objective the development of improved pastures for beef production in central Brazil was initiated in 1974. Records were available from 59 properties whose owners participated in an on-farm investment program with funds from the Central Bank of Brazil, through "CONDEPE" (National Council for Livestock Development). This was a semi-autonomous body working within the Ministry of Agriculture but now incorporated by EMBRATER.

No information was available in the area concerning the productivity of tropical grasses or their compatibility with legumes. The two experiments reported herein were designed to investigate the likely benefits of pasture improvement systems. When performing a grazing trial two different kinds of data may be obtained. The first refers to the performance of the animals grazing the pastures and the second refers to the responses of the pastures. In these experiments, both types of data were collected, and they will be presented separately for clarity.

Within the animal data several measurements were made; the ones presented here are:

a) Stocking rate

b) Liveweight gain per steer

c) Liveweight gain per hectare
d) Estimated TDN consumed per hectare
e) TDN consumption per kilogram of gain

Grazing Trial No. 1

Animal Data

Nitrogen fertilizer effects on animal production were mainly achieved through increasing stocking rate; N fertilizer had less effect on production per head (Table 3 and Figs. 6 and 7). The data indicate that given adequate N and suitable environment, N-fertilized tropical grass pastures have the potential to carry a large number of animals per hectare. Thus, relatively high productivity per unit area in the wet-dry tropics can be achieved (Table 3), but a lower productivity per animal. Stobbs (1976) reviewed animal performance from grazing experiments in the tropics. The mean annual liveweight gains were 0.35 kg/head/day and rarely exceeded 0.60 kg/day. Daily liveweight gains presented in Table 3 and Fig. 7 for grazing trial no. 1 and Table 6 and Fig. 15 for grazing trial no. 2, compare favorably with these levels and indicate that liveweight gains from grass-legume based pastures under the conditions of the Brazilian cerrados are similar to results from other tropical pasture species in different locations within the world tropics. However, the stocking rates at which these levels of weight gain were achieved varied between sites (Tables 3-6). This could be attributed mainly to rainfall.

Gir-Holstein steers gained up to 453 and 547 kg/ha/year in the grass-legume and in the N-fertilized grass pastures, respectively

(Table 3). As the quality of tropical pastures is improved, nutrients are wasted if genetically inferior stock are used to evaluate them; thus more productive animals are likely to utilize pasture more efficiently (Linehan et al., 1952). The limitation of using liveweight gain as the sole criterion for pasture evaluation in these circumstances is obvious, and the use of several parameters, or the reverse use of feeding standards so as to compare maintenance and production is essential. Exact information of feeding standards for some *Bos indicus* breeds may be lower than is generally stated for *Bos taurus* cattle. The production potential of the Gir-Holstein steers is reflected by the proportion of nutrients estimated as being utilized for production. The TDN required per kilogram of beef (Table 2) is an indirect measure of efficiency of utilization of the forage. The difference in efficiency from wet season to dry season found in this experiment was not very high. Quinn et al. (1961) on "Colonião" guineagrass found that from 2.5 to 3 times as much TDN was required for reach unit of gain during the dry season as during the wet season. This can be explained by differences in growth and associated chemical composition of the forages. While "Colonião" during the dry season has a high fiber and low protein content, the chemical composition of the forages used did not vary much with age or time of year (Table 4).

The difference in efficiency of utilization of the forages from summer to winter is striking (Table 2). Also, the grass-legume association was better utilized during winter than the N-fertilized grass. Animal performance was affected strongly by treatment and by seasonal conditions.

Table 2. TDN consumption per kg of gain

	'Guiné' grass + 100 kg N	'Guiné'grass + legumes
Dry season	19.47	17.61
Wet season	14.54	13.83
Difference between seasons (%)	33.91	27.33

Liveweight gains also showed seasonal variations. When each season was considered separately, there was practically no difference in the daily gain per animal between the two treatments. The explanation may be that the number of animals was maintained in equilibrium with the forage produced. However N fertilization of the grass pasture system resulted in a stocking rate higher ($P \leq 0.01$) than the grass-legume treatment (Table 3). These experimental results agree with those obtained by Groff and Harding (1970), in Australia and with those reported by Quinn et al. (1961) on "Colonião" guineagrass pastures in Brazil. It is believed that the 'Guiné' grass with 100 kg of N/ha produced close to maximum capacity. During the present experiment, the carrying capacity of the pastures was not known exactly, because the pastures were not stocked at capacity during both seasons. Therefore, optimum stocking rate for long-term output per unit would not be that which produces maximum liveweight in short spans (2 to 3 years), but as Mott (1960) stated, "Optimum stocking rate can only be defined as an optimum range and this stocking rate is somewhat below that which will give maximum product per area."

The stocking rates, during favorable times of the year, were increased purposely in order to maximize the utilization of the forage. Even with these increases in stocking rate, no reduction in average daily gain was detected. A reduction in average daily gain was reported also by Mears and Humphreys (1974) in which maximum output per unit area was reached when ADG had decreased by 25% in a grazing trial with Kikuyugrass Pennisetum clandestinum Hochst in Australia.

The liveweight gains per steer in the present grazing trial were correlated negatively to stocking rate. The desirable stocking rate is usually one which will produce an animal suitable for sale. In this trial this only occurred when the weight gains were in excess of 200 kg/steer. This not only meant greater liveweight gain per hectare, but it also enabled steers to reach marketable condition at least 1 year earlier than normal. It is important to remember that the area where the trial was located (low-fertility cerrado soil) was not regarded as good enough for fattening.

Pasture Data

Botanical composition. In order to achieve high levels of beef production on legume-based pastures, it is important to maintain an adequate proportion of legumes in the pasture. Beef production has

Table 3. Productivity of tropical grass as influenced by fertilizer and/or legumes, grazing trial no. 1

Seasons[c]	Treatments: Grass + Legume G + L	Treatments: Grass + N G + N	Differences[a] (G + L) minus (G + N)
Steers/ha--no. of head			
Average/dry	1.14	1.36	-0.22**
Average/wet	2.45	3.28	-0.83**
Annual average	1.92	2.22	-0.30
Daily gain/steer--g			
Average/dry	449	412	37
Average/wet	781	769	12
Annual average	615	590	25
Liveweight gain/steer--kg			
Average/dry	64	56	8
Average/wet	154	151	3
Annual average	218	208	10
Liveweight gain/ha--kg			
Average/dry	101	96	5
Average/wet	352	451	-99**
Annual average	453	547	-94**
TDN[b] required/kg/gain--kg			
Average/dry	17	19	-2
Average/wet	13	14	-1
Annual average	30	33	-3
Estimated TDN[b] consumed/ha-kg			
Average/dry	862	931	-69
Average/wet	2,533	3,405	-842**
Annual average (2 yr)	3,425	4,336	-911**

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[a] Significant at: **=1% level.

[b] Based on calculated requirements for maintenance and gain (Lucas, 1962).

[c] Number of days: dry season--136, wet season--196, annual--332.

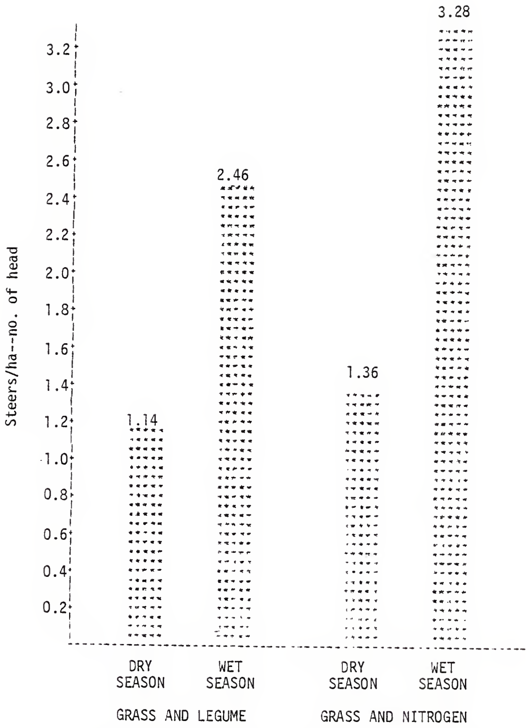

Fig. 6. Influence of treatment and season upon steers per hectare (no. of head), grazing trial no. 1.

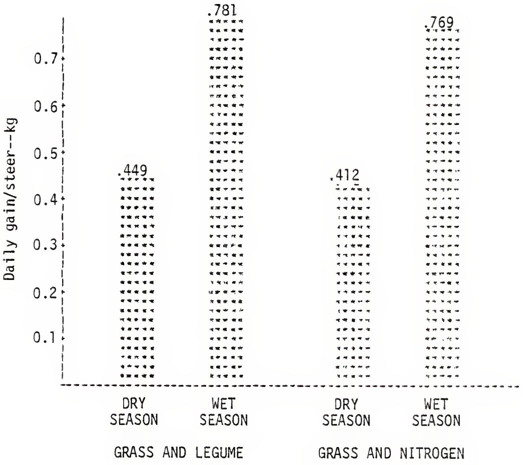

Fig. 7. Influence of treatment and season upon daily gain per steer (kg), grazing trial no. 1.

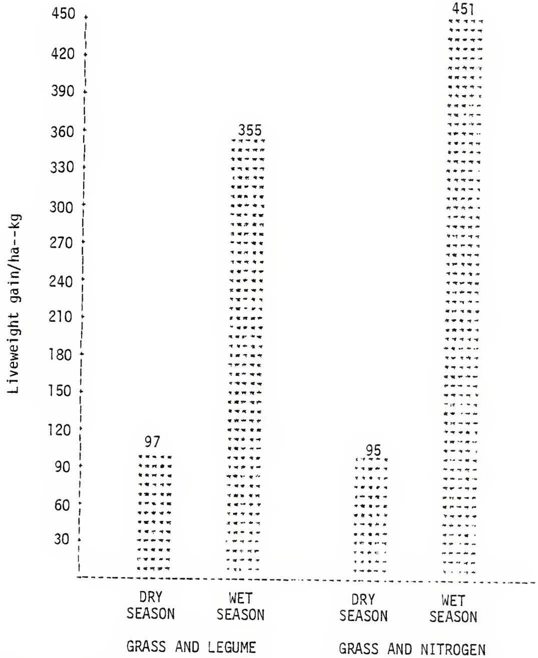

Fig. 8. Influence of treatment and season upon gain per hectare (kg), grazing trial no. 1.

been shown to be related to the proportion of legume in the sward. Evans (1970) showed that liveweight gain increased from 290 kg/ha to 540 kg/ha on swards with 13 and 35% legume, respectively. While optimum legume consumption has not been measured in grazing experiments, 20 to 30% legume measured on a dry matter basis would appear desirable (Stobbs, 1976).

In grazing trial no. 1, in the state of Minas Gerais, using a grass-legume association consisting of Panicum maximum cv. 'Guiné', Stylosanthes guianensis cv Schofield, Macroptilium atropurpureum cv Siratro and Glycine wightii cv Tinaroo, after 2 years of grazing (average stocking rate 2.3 head/ha), the botanical composition indicated that Glycine wightii was the most persistent of the legumes used in this experiment. There was a tendency for the percentage of Stylosanthes guianensis cv Schofield to decline over the period of the trial. This cultivar is very susceptible to the fungal disease anthracnose Collectotrichum gleiosporoides. Starting with 11% in the pasture, Stylo decreased continuously, and by the end of 1976 it constituted only 1.7%. The decrease in Siratro was possibly due to the infestation of diseases or to the effects of stocking rates and grazing pressures. The latter assumption is based on Jones' (1967) general conclusions on the sensitivity of Siratro to defoliation height. Close defoliation tends to remove the major portion of the young active leaf material and terminal meristems, leading to a reduced rate of recovery and ability to compete with the sown grass. Whether the lower survival under the grazing regime was due to selective pressure by the steers, trampling damage, or to a greater competitive advantage of the grass by the quick return of N from the grazing animal and from the legume components, cannot be resolved from the present data. All these factors, plus diseases, operating together resulted in a steady decline in the density of sown legumes. Overall, G. wightii had a higher survival rate than the other species and by October 1976, 6.4% was recorded for this legume.

The three legume components accounted for 10.6% of the available forage during the third year of the experiment. Total yield and percentage of Siratro were determined by stocking rate and to a lesser extent by grazing method (Tothill and Jones, 1977). The stocking rates were very conservative throughout the experiment but marked changes in grazing pressure could have occurred. Stocking rate had a marked effect on botanical composition and in particular on legume content.

Stobbs (1976) pointed out that 20 to 30% legume in the sward would appear desirable. The legume percentage (10.6%) for this grazing trial was less than the desirable level, but was near that reported by Bryan (1968a) and Evans (1970) who concluded that liveweight gain in steers was positively associated with legume content which varied from 13 to 35%. Also, in grass-legume pastures, the proportion of legume is crucial to the N balance in the system.

Siratro was not very persistent but proved to be a useful legume early in the wet season. A certain degree of unpalatability is a desirable trait in a pasture-legume because this adds to its persistence and enables it to grow, set seed, and fix N. Stobbs (1977) described the relative and seasonal palatability of Macroptilium atropurpureum in a mixture with a grass. Not only is spring growth of tropical grasses more palatable than M. atropurpureum, but spring grown material of this legume is less palatable than material grown later in the season. This enables the legume to grow undisturbed even under a continuous grazing system until late summer when the feeding value of the grasses begins to decline and the cattle select the legume in preference to the grass. The reseeding of the legume in the pasture is very important to ensure persistence. Heavy grazing may open up the sward and cause considerable invasion of weeds, under the conditions of the Brazilian cerrados.

In lightly grazed Siratro-grass pastures, cattle select grass in preference to Siratro in the spring and summer, whereas in late summer and autumn they prefer Siratro (Stobbs, 1977). Similar observations were made in the grazing trials conducted in central Brazil and reported here. Stobbs and Frazer (1971) reported diets of over 90% Siratro in autumn in mixed pastures of Macroptilium atropurpureum cv Siratro and Setaria anceps cv Kazungula. Under heavier grazing pressures, cattle eat Siratro throughout the year. This eventually results in lower Siratro yields.

Finally, and particularly in grass-legume pastures, the main concern about tropical legumes is not whether they fix N, but whether they persist.

Forage quality. The critical levels of minerals in the plant necessary for satisfactory plant performance are often equal to or higher than those required for animals. However, the concentration of many of the elements in plants decreases with age and season of the year and may fall below the animals' requirements. Plant analysis has been used effectively as a means of diagnosis of animal deficiencies. Knowledge of the mineral composition of pasture plants is of value to workers in animal nutrition for the detection of mineral imbalance. Nutritional disorders arising from an excess of certain minerals such as Se, Cu, and Mn can also be diagnosed by plant chemical analysis.

Phosphorus: The NRC (1976) recommendation for steers weighing 450 kg is 0.18% of P in the dry matter consumed. According to this criterion, the amount of P found in the grass-legume mixture was sufficient during both seasons to meet the requirement of the grazing animals. The analysis of variance for forage P presented in Appendix Table A-6 showed a difference ($P<0.0001$) between treatments. It is interesting to note that in the grass-N pasture system forage P was borderline or deficient in both seasons (Table 4), even with the basal P fertilization used to establish the pasture. A complete mineral mixture including trace minerals and salt was fed free choice, which should have met the grazing steers' requirements.

Calcium: The NRC (1976) dietary Ca recommendation for growing and finishing steers is 0.18%. The analysis of variance presented in Appendix Table A-6 showed significant differences between treatments and between seasons ($P<0.0001$). In both seasons Ca was sufficient to meet the requirements of grazing animals. Calcium deficiency in forages for grazing ruminants is rare and has not been reported in Brazil.

The grass-legume association had higher Ca concentrations than the N-fertilized grass treatment. This was because legumes are generally higher in Ca than grasses and some tropical pasture legumes are more efficient than their counterparts at extracting Ca from the soil (Andrew and Norris, 1961).

Crude protein: The N values presented in Table 4 for both treatments and seasons were converted to crude protein by multiplying them by the factor 6.25. Deficiencies of protein in tropical grasslands often limit ruminant production for much of the year. Milford and Minson (1966) observed that a marked decline in intake of tropical grasses occurred when the CP content fell below approximately 7%; above this level it has little effect on intake. They concluded that the lack of crude protein for the rumen flora may have caused a low-energy intake which was responsible for the low feeding values of many mature tropical grasses. This low crude protein content also may influence *in vitro* digestion by depriving the rumen fluid bacteria of some of their N requirements (Waldo, 1968).

The analysis of variance for the forages analyzed is presented in Appendix Table A-6. A difference between seasons ($P<0.0001$) and between treatments ($P<0.0001$) was evident. The crude protein level of the pasture samples was always higher than 7%, the critical level (Table 4). Levels of crude protein for both pasture system treatments demonstrated clearly that the grass-legume association had higher protein contents ($P<0.0001$) in both seasons (Table 4).

Table 4. Forage calcium, phosphorus, nitrogen and protein means and standard deviations (S.D.) as related to season, pasture and pasture treatment (grazing trial no. 1), 1975-1976

Pasture Treatment	N[b]	Forage Quality Parameters[a]			
		Ca	P	N	Protein
		Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.
		%	%	%	%
		Wet Season			
Guineagrass + 100 kg N/ha	24	0.39 ± 0.05	0.16 ± 0.02	1.77 ± 0.21	11.31 ± 1.44
		Dry Season			
Guineagrass + 100 kg N/ha	21	0.35 ± 0.03	0.14 ± 0.01	1.61 ± 0.14	10.10 ± 0.88
		Wet Season			
Guineagrass + legumes[c]	24	0.52 ± 0.07	0.25 ± 0.04	2.05 ± 0.11	12.82 ± 0.73
		Dry Season			
Guineagrass + legumes[c]	21	0.44 ± 0.04	0.21 ± 0.02	1.87 ± 0.03	11.71 ± 0.21

[a] Values for all forage quality parameters expressed on a dry matter basis.
[b] Number of observations.
[c] Legumes: *Macroptilium atropurpureum*, *Glycine wightii*, and *Stylosanthes guianensis*.

The voluntary intake of tropical legumes is usually higher than that of tropical grasses (Milford and Minson, 1966) due to shorter retention time in the rumen and a greater packing density in the rumen (Thornton and Minson, 1973). A high legume content is, therefore, usually desirable to achieve high year-round beef production.

It is possible to conclude that at a given stage of maturity, the legume component will usually have a higher protein content and a higher content of some minerals. These comparisons indicate the importance of the legume in providing a pasture component with a higher feeding value than the associated grasses. In fact this is the most important role of the legume particularly in the dry season where the legume becomes a major source of available feed.

Economic Assessment of Beef Production from Grass-Legume versus Nitrogen-Fertilized Grass Pasture in Central Brazil

The breakeven liveweight prices for grazing trial no. 1 were calculated considering two beef price levels and two N fertilizer price levels (Table 5). Costs and returns were estimated based on the actual grazing trial results.

Comparing the two pasture systems (Table 5) at the Cr$ 21.00 per kg beef price and N fertilizer at Cr$ 10.00 per kg of N, slightly improved economic performance resulted from a N-fertilized grass pasture. However, if the price of N doubles (Cr$ 20.00 per kg of N), there would be an economic advantage in using a grass-legume based system.

Table 5. Economic assessment of beef production from grass-legume vs. nitrogen-fertilized grass pastures in central Brazil

	'Guiné' grass + legumes	'Guiné' grass + 100 kg N
Stocking rate steers/ha	1.80	2.38
Average beef sold annually kg/ha[a]	245	295
Increase due to N kg/ha	-	50
A. Value of extra beef kg/ha		
at Cr$ 7.00 per kg (B_1)	1,715	2,065
at Cr$ 21.00 per kg (B_2)	5,145	6,195
B. Cost of N 100 kg/ha		
at Cr$ 10.00 per kg of N	-	1,000
at Cr$ 20.00 per kg of N	-	2,000
C. Other costs/ha[b]	3,776	3,776
D. Total costs/ha		
at Cr$ 10.00 per kg of N (N_1)	3,776	4,776
at Cr$ 20.00 per kg of N (N_2)	3,776	5,776
Returns (Cr$)		
(A - D)		
$B_1 - N_1$	-2,061	-2,711
$B_1 - N_2$	-2,061	-3,711
$B_2 - N_1$	1,369	1,419
$B_2 - N_2$	1,369	419
Liveweight price per kg required to break even		
at Cr$ 10.00 per kg of N	15.41	16.19
at Cr$ 20.00 per kg of N	15.41	19.58

[a] Assuming the price of dressed meat to be Cr$ 105.00 and Cr$ 315.00 per arroba (15 kg of dressed meat) and dressing percentage to be 54%.

[b] Complicating factors such as interest on fertilizer investment, capital rationing and risk are disregarded in this presentation. Infrastructure costs are prorated over a 10-year period. Other costs involved in the establishment of the pasture system were not prorated in the calculations.

Yields under ranch conditions may be lower than trial yields. If ranch yields are 80% of trial yields, then it is unlikely that a N fertilizer based system would provide additional profit except where N prices are low and high rates are applied.

Figure 9 presents liveweight price per kilogram required to break even when the prices of N are compared to the prices of beef. When considering the N-fertilized grass pasture system and assuming the prices of N to be Cr$ 10.00 and Cr$ 20.00 per kg, the breakeven price per kilogram of beef would be Cr$16.19 and Cr$ 19.58, respectively.

The optimum level of beef production is not governed only by biological efficiency but also by the economic efficiency of the particular production system chosen. In the future, it also is likely that energy efficiency of a given technology will affect economic efficiency.

Since fossil fuels are being depleted rapidly (Hammond, 1972) and prices for energy are likely to rise appreciably, consideration needs to be given to pasture production systems which conserve energy. Relative energy inputs for the alternative beef production systems in the tropics have not been calculated, but N-fertilized pastures are at a distinct disadvantage since high and repeated applications are necessary. One kilogram of N requires 77 MJ (including production and processing) compared with 14 MJ and 10 MJ for each kg of P and K, respectively (Pimentel et al., 1973).

Natural gas is the primary fuel (955) used to produce anhydrous ammonia. The current and projected natural gas dependency on chemically

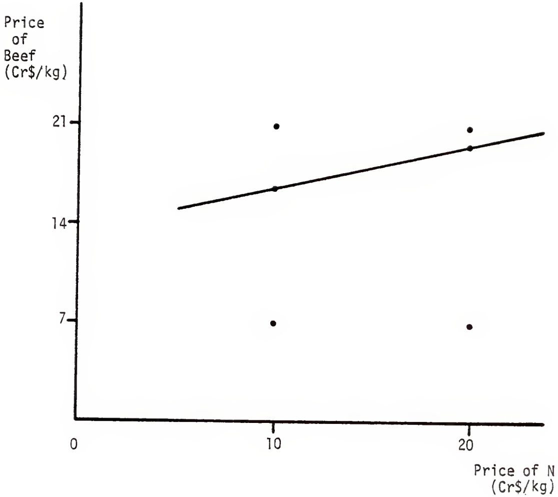

Fig. 9. Liveweight price per kilogram required to break even.

fixed N fertilizer remains as one of the most flagrant violations of good economics, use of a nonrenewable resource.

There is considerable merit to developing grass/legume production systems where suitably adapted legumes are available. In most areas of the tropics grass/legume based pastures undoubtedly offer the best prospect for profitably increasing feed supplies and thus beef production (Stobbs, 1969a; Davies and Hutton, 1970). Other studies (Nuthall and Whiteman, 1972) suggest that unless N price is low and beef price high, N systems are less profitable.

Grazing Trial No. 2

Animal Data

The role of tropical legumes in increasing production of a green panic grass system was studied in the state of Goiás, central Brazil. In the first year of the trial, animal performance was affected strongly by the severe incidence of foot-and-mouth disease during the dry season. Furthermore, Centrosema is slow to establish in the first year, and it contributed less N and biomass to the grazing system.

The results indicate that daily liveweight gains showed seasonal variation with gains of 0.100 kg/head/day in the dry season and 0.665 kg/head/day in the wet season, for the grass-legume association.

For the same year, the daily liveweight gain from the unfertilized jaraguagrass was greater than the grass-legume treatment (0.294 kg/head). Because this unexpected result did not occur in the second year of the experiment, it is suggested that the incidence of foot-and-mouth disease was stronger from the green panic-legume mixture. The decline in legume content is the most likely explanation for the reduced gains. As a consequence, the output per area was depressed, even though no significant difference was found between treatments. When results were computed for both seasons, the yearly average showed that liveweight gains were 156 kg/ha/year for the unfertilized jaraguagrass system and 418 kg/ha for the grass-legume system, which had received P and K (Fig. 12).

When data for the second year of the grazing trial are considered, higher gains for the rainy vs. dry season are shown (Fig. 15 and Fig. 16). Despite these similar overall trends, steers grazing pastures of the green panic-legume system gained more weight than animals on the unfertilized jaraguagrass pasture. This advantage was apparent at most times of the year, but it was particularly marked and consistent in the dry season. Steers from the grass-legume fertilized pasture entered the next wet season in better condition than animals on unfertilized jaraguagrass pasture and they maintained this advantage.

Data were collected for the production over the 2 years (676 days) of the trial. They are expressed as liveweight gain per hectare and are presented in Table 6 and therefore the liveweight gain, expressed as an annual average for the 2 years, was 161 kg/ha for the unfertilized jaraguagrass system and 361 kg/ha for the fertilized grass-legume system. Over the duration of the grazing trial, an increase of 200 kg/ha in liveweight gain, i.e., 124% was recorded from legumes and fertilizer, when compared to grass system. An analysis of variance using years as replicates showed that there was no interaction ($P>0.05$) between treatments and years.

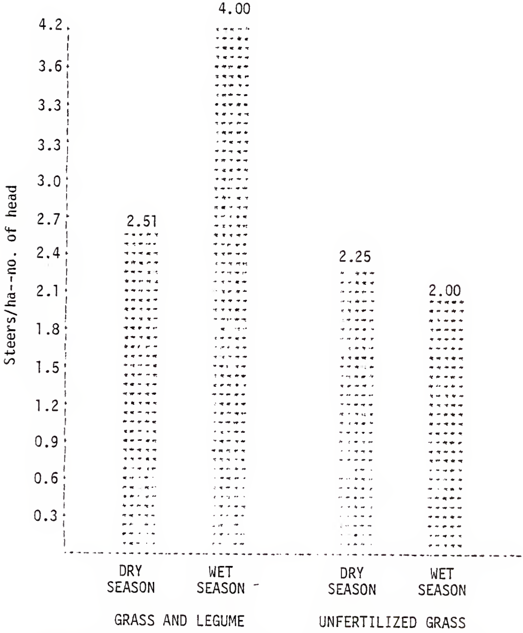

Fig. 10. Influence of treatment and season upon steers per hectare (no. of head), grazing trial no. 2--first year.

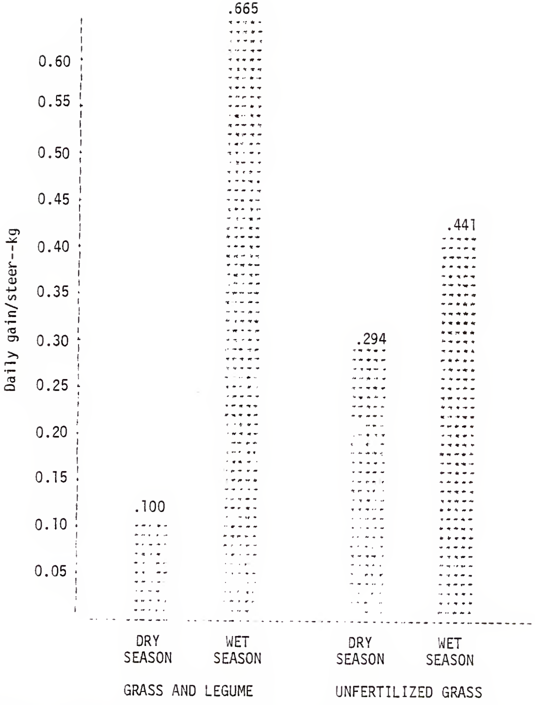

Fig. 11. Influence of treatment and season upon daily gain per steer (kg), grazing trial no. 2--first year.

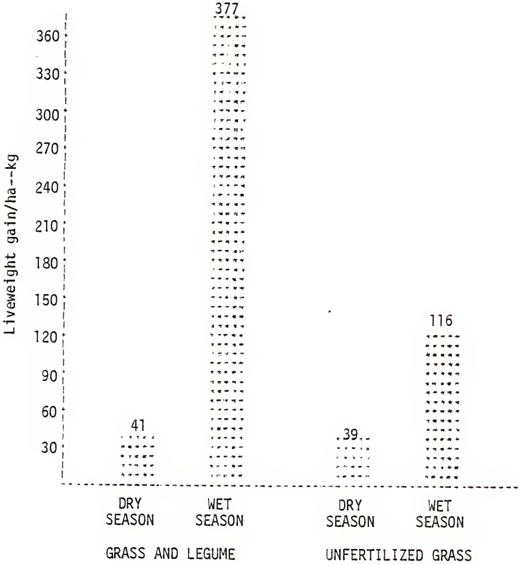

Fig. 12. Influence of treatment and season upon gain per hectare (kg), grazing trial no. 2--first year.

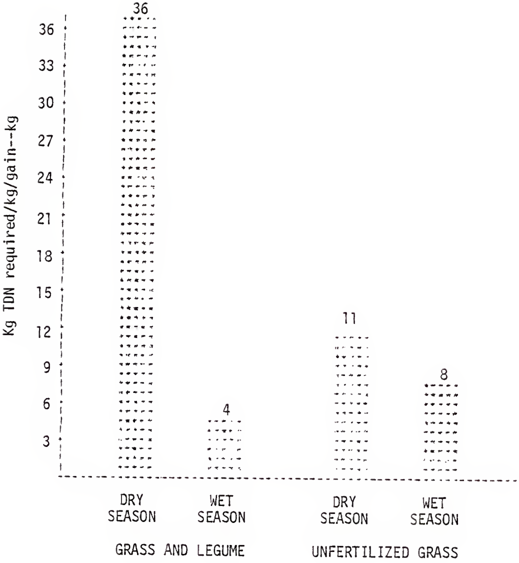

Fig. 13. Influence of treatment and season upon kg of TDN required per kg of gain (kg), grazing trial no. 2--first year.

The combination of higher gains per head with the legume mixture plus higher stocking rates led to large increases in gain per hectare (Table 6).

A mean stocking rate of 2.40 steers/ha was maintained over the 2 years of the trial for the grass-legume system. For the untreated grass system, only 1.52 animals/ha was achieved (Table 6). The grass-legume system had a higher carrying capacity ($P<0.001$) than the unfertilized grass system.

Actual stocking rates for the second experimental period (Table 6) mostly were held constant. Occasionally, and mainly at the end of the wet season, minor adjustments were made to maintain grazing pressure near the optimum.

It has been demonstrated by several authors (Blaser et al., 1956, 1960; Harlan, 1958; Mott, 1956, 1960) that the maximum product per hectare is obtained when pastures are grazed at their optimum carrying capacity. This point is of special interest in the present study, because the carrying capacity of the pastures was not known exactly and the treatments were not always at the stocking rate that they theoretically should have been.

In the third year after establishment of the pasture, a decline in the liveweight gains from the grass-legume pasture system was observed (Table 6). The most likely explanation for this was the decrease in legume content (Table A-7). At Beerwah, in southeast Queensland, Australia, Bryan (1968) and Evans (1970) concluded that liveweight gain in steers was associated positively with legume content, which varied from 12 to 39%.

Table 6. Productivity of tropical grass as influenced by fertilizer and/or legumes, grazing trial no. 2

Seasons[c]	Treatments: *P. max.* + Legume (G + L)	Treatments: *H. rufa* no Legumes	Differences[a]: (G + L) minus *H. rufa*
Steers/ha--no. of head			
Average/dry	2.00	1.55	0.85
Average/wet	2.80	1.49	1.31*
Annual average (2 yr)	2.40	1.50	0.88*
Daily gain/steer--g			
Average/dry	221	268	-47
Average/wet	660	534	126
Annual average (2 yr)	441	400	41
Liveweight gain/steer--kg			
Average/dry	33	25	8
Average/wet	117	100	17
Annual average (2 yr)	150	125	25
Liveweight gain/ha--kg			
Average/dry	60	34	26
Average/wet	301	127	174**
Annual average (2 yr)	361	161	200*
TDN[b] required/kg/gain--kg			
Average/dry	22	11	11
Average/wet	5	7	- 2
Annual average (2 yr)	27	18	9
Estimated TDN[b] consumed/ha-kg			
Average/dry	1,011	426	585
Average/wet	1,905	942	963
Annual average (2 yr)	2,916	1,368	1,548

[a] Significant at: *=5%; **=1% level.

[b] Based on calculated requirements for maintenance and gain (Lucas, 1962).

[c] Number of days: dry season--146, wet season--192, annual--338.

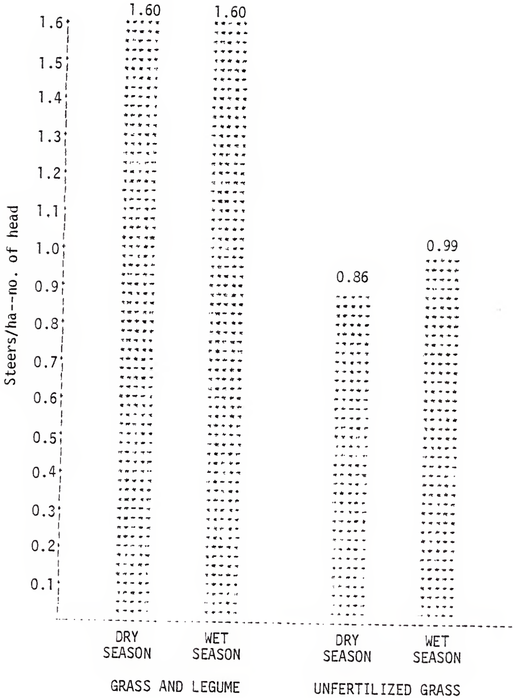

Fig. 14. Influence of treatment and season upon steers per hectare (no. of head), grazing trial no. 2--second year.

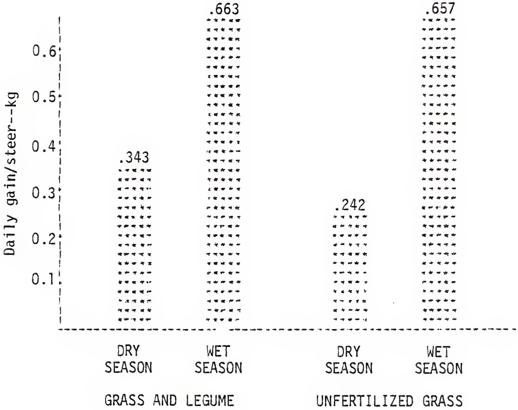

Fig. 15. Influence of treatment and season upon daily gain per steer (kg), grazing trial no. 2--second year.

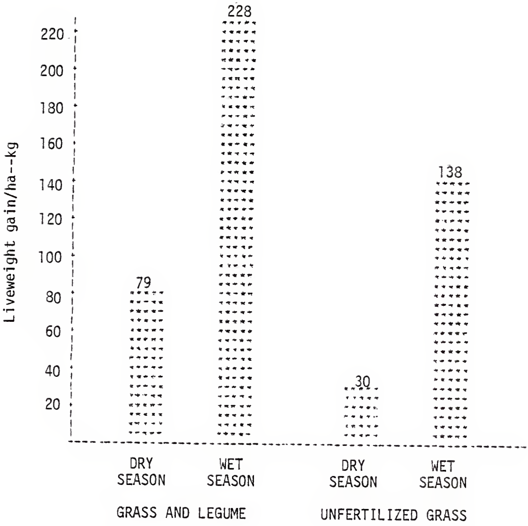

Fig. 16. Influence of treatment and season upon gain per hectare (kg), grazing trial no. 2--second year.

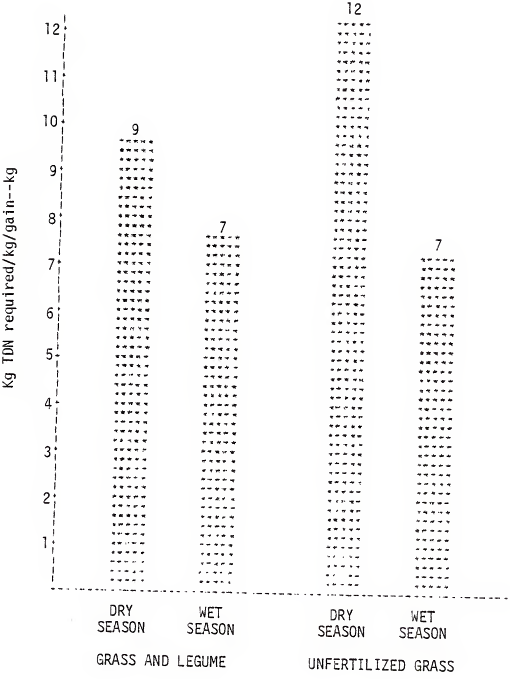

Fig. 17. Influence of treatment and season upon kg of TDN required per kg of gain (kg), grazing trial no. 2--second year.

The reduction in liveweight gains, for the grazing period 1977-1978, suggested that maintenance dressings of P might be necessary after the third year. It also suggests that the green panic-legume mixture may require the higher level of soil fertility which existed early in the experiment.

The differences in production between pasture systems in each grazing period are clearly demonstrated in Figs. 10-13. It is suggested that the level of animal production that can be attained in the grass-legume systems in the Brazilian cerrados is dependent on the legume content of the pastures, the level of available nutrients and grazing management.

By accident, and against the will of the experimenter, one replication of treatment 2 (unfertilized jaraguagrass pasture) was lost. Because the jaraguagrass system treatment was not replicated, major consideration must be placed on changes in production over time within treatments. An unweighted analysis of variance of the parameters gain per head, gain per hectare and animals per hectare for treatments for the 2 years was carried out, and treatment effects were tested against the replications within years and treatments. This indicated a differance ($P<0.03$) for gain per hectare, between treatment means. From past history of this property, it was known that differences in animal performance of the magnitude recorded are not common. Because data on forage systems are generally not available, exploratory experiments with many systems at the sacrifice of replication can speed up progress (Blaser et al., 1974). Ideas for advancing livestock production and for implementation into farm practices all over the world can result from systems of forage-livestock management rather than from replication, fixed stocking rates, and isolated pieces of sophisticated research.

After exploratory research with forage-animal systems, refinements of a few of the best systems along with stocking rates and new innovations may be evaluated in replicated experiments. Lack of replication, when exploring forage-animal systems, sacrifices reliability of data on a land area basis. However, data on animal performance can be reasonably reliable without replication, if grazing pressures are controlled. The final practicality of a forage-animal system will be ascertained by its use and economic analyses on farms in various ecosystems rather than from research per se (Blaser et al., 1974). The usefulness of unreplicated experiments or experiments with a missing replication was stressed by 't Mannetje, Jones and Stobbs (1976, p. 213):

> These are usually simple experiments which may be used in the early stages of pasture development programs. They are often used to demonstrate to landholders the value of an improved pasture for animal production. Their usefulness is greatest when large differences are to be expected, as for example in comparisons between native pastures and improved pastures.

Continuation of unreplicated trials over several years will increase the validity of the treatment means, but this does not constitute true replication. Petersen and Lucas (1960) estimated that the error (C) per pasture will be reduced approximately to C/Y, where Y is the number of years. Another way of increasing the value of the results of this kind of trial is to use a large number of animals in each treatment. This has the added advantage that the trial is more closely related to farm practice. An example of this type of experimentation has been described by Shaw (1961) and Shaw and 't Mannetje (1970).

Unreplicated tests may also be carried out for exploratory reasons, for example to obtain a first approximation of the likely stocking rates applicable in a new environment. It may be more important to evaluate four mixtures without replication than one with four replications.

The design of grazing trial no. 2 was not ideal, but larger experiments are often impractical at the private ranch level. Two or more replicates of treatments, in the trial described, would have added accuracy to the results. When production differences are expected to be large, a relatively simple grazing trial of this type is of value, but as differences become smaller more refined techniques will be necessary.

Restrictions in design are reflected in the assumptions which are necessary to justify the results. Treatments behaved in a similar manner in each of the 2 years that the trial was conducted, making the interpretation of results easier. The use of years as replicates gave a good measure of significance.

The type of trial carried out does not permit a precise assessment of the optimum stocking rate for such pasture systems. It is clear, however, that steer numbers can be more than doubled and, in fact, the grass-legume pastures have been stocked at almost three times the average rate for the jaraguagrass pasture system.

When comparing output per hectare for the individual years of the experiment, 1975-1976 and 1977-1978, results followed a similar trend in production. This would indicate that results are repeatable.

Regardless of the limitations of this research, the results offer promise for improvement of production and better utilization of pasture systems.

Pasture Data

Botanical composition. Measurements of yield and botanical composition need to be continued over a number of years to gain an understanding of the trends in persistence. Measures of population changes are then especially important. Thus, it may be anticipated that species x management interactions will become apparent with time, and there will often be changes in botanical composition as a pasture becomes older.

With grass-legume pastures the changes over time tend to follow changes in the proportion of legume and are associated with changes in the N supply. It is common to have a period of legume dominance which gives rise to a build-up of available N which then leads to a period of grass dominance; this in turn leads to a decline in available N, thus creating conditions favorable for another period of legume dominance. Because cyclical patterns of botanical change such as this are common, conclusions based on short-term changes should be viewed with considerable caution.

Over the 2-year period of this trial, there was a tendency for the percentage of green panic and *Centrosema pubescens* to increase with time (Table A-7). Initially, the percentage of *Stylosanthes* was 26.8, with a marked decline in the final year of the experimental period. The final botanical determination (1978) revealed that *Stylosanthes guianensis* constituted only 2.5%. Its poor performance in this trial, could have been due to fungal diseases, or to the grazing management imposed.

Overall Centrosema pubescens had a higher persistence and contributed to higher animal production in the grass-legume pasture system, because of the higher quality of the feed ingested. Botanical composition, if it was affected by the fertility status of the soil, diseases or stocking rate, affected animal performance through variations in the quality of the diet, due to reduction in legume content.

Because green panic remains somewhat green for much of the dry season in association with the legumes, it was responsible for maintaining a ground cover that was photosynthetically productive for the entire year.

The results suggest that the decline in legume persistence might be attributed to the use of unadapted species not tolerant to fungal diseases. Furthermore, the grazing management should aim at a level of utilization that does not cause complete removal of growing runners and young leaves which will reduce regrowth potential to a level where the legumes can no longer compete with the associated grass. The analysis of variance is presented in Appendix Table A-8. A difference between years ($P<0.0001$) and sepcies ($P<0.0001$) was evident.

Forage quality. Calcium and phosphorus: Composite forage samples were used to assess plant composition. Apart from a higher N content, tropical legumes generally maintain higher Ca concentrations in plant tops than the companion tropical grasses. Andrew and Robins (1969c, 1971) gave values of Ca concentration for seven tropical legumes and nine tropical grasses grown in nutrient cultures. Calcium concentrations for the legumes ranged from 1.13 (D. intortum) to 1.93% (S. humilis) and for the grasses from 0.17 (Digitaria decumbens) to 0.41% (Chloris gayana). Furthermore, tropical legumes are more efficient at extracting Ca from soils low in Ca than are temperate legumes (Andrew and Norris, 1961).

Comparisons of P concentration are more variable, depending on species, plant age and season. For example, Whiteman (1969) reported a mean value of 0.22% P for four tropical legumes grown with Rhodesgrass under grazing cutting.

The forage data in Table 7 shows the Ca, P, Mg, and K concentrations in forage components for both seasons. The analysis of variance presented in Table A-5 indicates differences between seasons.

The data make it clear that the legumes contained more Ca than the highest level in the grasses (Table 7). Gomide (1969) reported that in the case of Ca, tropical legumes have higher calcium concentrations than tropical grasses.

The high percentage of forage Ca in the dry season is probably due to the low mobility of Ca in plant tissue. This lack of Ca translocation from one organ to another causes an increase of Ca in old plant tissue. Gomide (1969) indicated that Ca is relatively immobile and the concentration increases in old organs and stems. This observation also agrees with Blue and Tergas (1969). In both seasons Ca was sufficient to meet the requirements of the grazing steers. The results presented in Table 7 agree with Jardim et al. (1966) and Gallo et al. (1974).

The P data (Table 7) indicates that except for jaraguagrass, the forages meet the NRC (1976) requirements for growing and finishing steers. The analysis of variance for forage P presented in Table A-5 demonstrated a difference ($P<0.002$) between dry and wet seasons.

The decline in P content as the dry season progressed is in agreement with Blue and Tergas (1969) who reported some losses of nutrients due to translocation to the root system. Several researchers in Brazil have reported low levels of P during the dry season, Jardim el al. (1962b), Teixeira et al. (1971) and Gallo et al.(1974).

The poor P status of many tropical soils is offset to some extent by the fact that many tropical legumes adapted to such soils are highly efficient at extracting or mobilizing P (Andrew and Robins, 1969a).

Magnesium and potassium: The requirement of Mg for finishing steers is 0.04 to 0.10% of dry matter. The amount of Mg in the forages on both treatments was sufficient to meet the animal requirements.

The analysis of variance for forage Mg presented in Table A-5 demonstrates differences ($P<0.005$) between dry and wet season. Table 7 presents the mean values for Mg content. The G. panic values agree with Andreasi et al. (1968) who reported higher levels of Mg during the dry season and lower values during the wet season.
The analysis of variance for forage Mg in Table A-5 indicates a

Table 7. Forage calcium, phosphorus, magnesium and potassium means and standard deviations (S.D.) as related to season and forage component (grazing trial no. 2)

Forage Component	N[b]	Forage Quality Parameters[a]							
		Ca		P		Mg		K	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
		%							
Wet Season									
Green Panic	7	0.32	± 0.08	0.24	± 0.10	0.27	± 0.05	1.31	± 0.47
Legumes[c]	5	0.77	± 0.27	0.23	± 0.01	0.27	± 0.02	1.58	± 0.45
Jaraguagrass	3	0.40	± 0.03	0.14	± 0.01	0.19	± 0.01	1.25	± 0.06
Dry Season									
Green Panic	6	0.51	± 0.01	0.20	± 0.01	0.43	± 0.01	1.29	± 0.02
Legumes[c]	6	0.74	± 0.06	0.20	± 0.02	0.26	± 0.01	1.07	± 0.01
Jaraguagrass	3	0.48	± 0.03	0.07	± 0.02	0.18	± 0.02	0.36	± 0.02

[a] Values for all nutrients expressed on a dry matter basis.

[b] Number of observations.

[c] Legumes: *Centrosema pubescens* and *Stylosanthes guianensis*.

Table 8. Forage molybdenum, zinc, copper, cobalt and manganese means and standard deviations (S.D.) as related to season and forage component (grazing trial no. 2)

Forage Component	N[b]	Forage Micronutrients[a]									
		Mo		Zn		Cu		Co		Mn	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
		ppm									
Wet Season											
Green Panic	7	1.21 ±	0.57	13.1 ±	1.92	4.07 ±	3.72	0.29 ±	0.23	61.04 ±	38.78
Legumes[c]	5	1.22 ±	0.62	10.7 ±	0.29	9.04 ±	0.69	0.66 ±	0.14	19.96 ±	3.19
Jaraguagrass	3	1.59 ±	0.91	11.1 ±	1.36	1.67 ±	0.52	0.18 ±	0.06	34.00 ±	10.99
Dry Season											
Green Panic	6	1.53 ±	0.11	31.1 ±	1.24	1.38 ±	0.12	0.40 ±	0.39	43.90 ±	7.62
Legumes[c]	6	1.70 ±	0.34	19.2 ±	6.40	8.91 ±	0.66	0.72 ±	0.19	67.50 ±	15.37
Jaraguagrass	3	1.04 ±	0.50	12.4 ±	1.44	1.25 ±	0.25	0.12 ±	0.04	47.20 ±	1.66

[a] Values for all nutrients expressed on a dry matter basis.

[b] Number of observations.

[c] Legumes: _Centrosema pubescens_ and _Stylosanthes guianensis_.

interaction ($P<0.0001$) between season and forages. Green panic had a higher Mg level (0.43%) in the dry season than in the wet season (0.27%).

The K requirement for growing and finishing steers is between 0.60 and 0.80% of the dry matter intake (NRC, 1976).

Andrew and Robins (1969c) established a critical K percentage of 0.75 in Siratro sampled at the immediate preflowering stage of growth.

In this grazing trial, K content ranged from 0.36% for jaraguagrass to 1.58% for the legumes. Except for jaraguagrass in the dry season, the K concentrations were above the critical K percentages, which suggests that K per se did not limit the forage growth. Again, except for jaraguagrass during the dry season, the forage K levels are considered adequate for grazing steers.

The analysis of variance for forage K in Table A-5 showed a difference ($P<0.002$) between seasons. The forage K content during the dry season was lower than during the wet season (Table 7). Blue and Tergas (1969) reported that K losses from the forage were probably due to translocation to the root system.

Forage K also showed a interaction ($P<0.07$) between season and forage components. Higher K levels were found during the wet season when the legumes contained 1.58% and green panic 1.31%.

Table 7 presents the mean values for K content.

Molybdenum and copper: Molybdenum is an essential micronutrient for all legumes, because of its important role in the symbiotic fixation of N (Anderson, 1956). When grown on soils low in available N, a Mo-deficient legume presents a picture of N starvation, typical of ineffective nodulation. Molybdenum becomes progressively less available as soil acidity increases. For this reason many reported responses to lime have in fact been responses to available Mo.

Cattle requirement for molybdenum is 0.01 ppm or less (NRC, 1976) and toxicity is 6 ppm (NRC, 1978), when diets contain low Cu concentrations. Molybdenum deficiency for grazing cattle under practical conditions was not found in the literature.

The analysis of variance for forage Mo presented in Table A-5 did not show a difference between dry and wet seasons. Although no significant differences were found among forage components, it is important to note that jaraguagrass had a higher level of Mo, in the wet season, and lower in the dry season than the other species.

The forage Cu dietary requirement for growing and finishing steers is 44 ppm (NRC, 1976). The analysis of variance for forage Cu shown in Table A-5 did not show a difference between dry and wet season. Forage Cu during the wet season was 9.04 for the legumes and 1.67 ppm for the jaraguagrass, which indicates a deficiency in jaraguagrass (Table 8).

The analysis of variance for forage Cu presented in Table A-5 showed a difference ($P<0.0001$) among forage species. Legumes had the highest Cu mean among the forages analyzed. The dietary Cu concentrations in the legumes were adequate for finishing steers in both seasons.

Cobalt: Definite proof that Co plays a role in symbiotic N fixation is of recent origin. The essentiality of Co for the growth of the rhizobia was demonstrated by Lowe and Evans (1962) with rhizobia for alfalfa, clover, pea and beans.

The NRC (1976) dietary Co requirement for grazing cattle is between 0.05 and 0.10 ppm. The analysis of variance presented in Table A-5 did not show a difference between seasons. However, in the same table there is shown a difference ($P<0.003$) among forage species. The values during both seasons were considered above the minimum requirements for grazing cattle according to the NRC (1976).

Zinc: The dietary Zn requirements for growing and finishing steers is 20 to 30 ppm (NRC, 1976). The analysis of variance for forage zinc presented in Table A-5 showed a difference ($P<0.0001$) between seasons. Table 8 presents the mean values for each season. Except for green panic in the dry season (Zn level of 31.1 ppm) the Zn levels in the forage components analyzed were considered deficient to meet the requirement of grazing cattle.

The analysis of variance presented in Table A-5 indicated a difference ($P<0.0001$) among the forage species studied. It is interesting to note that green panic had the highest Zn mean of 31.1 ppm in the dry season.

Table 9. Forage *in vitro* organic matter digestibility, nitrogen, and protein means and standard deviations (S.D.) as related to season and forage component (grazing trial no. 2)

Forage Component	N[b]	Forage Quality Parameters[a]		
		IVOMD	N	Protein
		Mean S.D.	Mean S.D.	Mean S.D.
		%	%	%
		Wet Season		
Green Panic	7	43.81 ± 3.44	1.06 ± 0.37	6.64 ± 2.32
Legumes[c]	5	49.80 ± 0.60	2.20 ± 0.04	13.75 ± 0.28
Jaraguagrass	3	36.03 ± 1.04	0.90 ± 0.14	5.62 ± 0.86
		Dry Season		
Green Panic	6	42.60 ± 0.35	1.04 ± 0.08	6.51 ± 0.48
Legumes[c]	6	43.50 ± 0.89	2.09 ± 0.01	13.11 ± 0.09
Jaraguagrass	3	32.23 ± 6.21	0.65 ± 0.02	4.06 ± 0.11

[a] Values for all nutrients expressed on a dry matter basis.
[b] Number of observations.
[c] Legumes: *Centrosema pubescens* and *Stylosanthes guianensis*.

Manganese: The NRC (1976) reported that the manganese requirement for growing and finishing steers is between 1 and 10 ppm. The analysis of variance in Table A-5 indicates an interaction between season and species ($P<0.0019$). Sufficient manganese was available on all species to meet the requirements of grazing cattle. These data agree with Sousa (1978), who reported that manganese levels from pastures in the state of Mato Grosso, Brazil, were adequate to meet the requirements of finishing steers.

Crude protein: The crude protein content of forage dry matter is an important characteristic for determination of the nutritional status of the animal. Minson and Milford (1967), cited by Moore and Mott (1973), suggest that the level of crude protein below which N is the first limiting factor in tropical forages is about 7% on dry matter basis. Most grasses fall below this level in the dry season but the presence of a legume in the pasture, even if frosted, usually provides sufficient protein to meet the animal's requirements for maintenance and production (Milford, 1960). Moore and Mott (1973) suggest that the crude protein percentage be examined first when an explanation of unexpected low production is observed before looking for other limitations such as those related to structure, other nutrients and toxic agents.

The analysis of variance for crude protein is presented in Table A-5 which indicates no difference ($P>0.05$) between seasons. However, the same table reveals a difference ($P<0.0001$) among forage species. Table 9 presents the mean values for each season. Green panic had borderline deficiency protein levels, while jaraguagrass was below the critical level in both seasons. In the grass-legume pasture system the presence of the legume should provide sufficient protein to meet the animal's requirements.

In vitro organic matter digestibility: It is well accepted that the output per animal is a function of the intake of digestible nutrients (Mott and Moore, 1970; Burton, 1970; Van Soest, 1973), and it is within this context that digestibility is recognized as an important measure of forage quality.

The analysis of variance for IVOMD is presented in Table A-5 and indicates differences ($P<0.003$) between seasons, and between forage species ($P<0.006$). The same analysis of variance for IVOMD reveals an interaction ($P<0.03$) between season and forage species. Table 9 presents mean values for each season. The legumes had higher IVOMD values than grasses.

In order to achieve high levels of animal production, the intake of digestible nutrients must be adequate for maintenance and production.

The critical value for N for maintenance of N balance in ruminants is 1.15% (Milford and Haydock, 1965) but the content in grasses in grass/legume pastures often falls below this, particularly in the dry season. Although low quality grass may be utilized more efficiently if adequate legume is present, a fall in legume content will affect the overall efficiency of utilization of the pasture.

Minson and Milford (1967), using pangolagrass, found that the digestible dry matter intake was linearly related to the legume content when there was >10% legume in the diet, and concluded "as the proportion of legume in the diet is increased from 0 to 100% there is an increase in the voluntary intake of the entire diet, an increase in dry matter and crude protein digestibilities and a corresponding reduction in liveweight losses." Similar results were obtained in the grazing trials reported herein. A detailed examination of the botanical composition, in both experiments, indicates a reduction in legume content. This reduction was probably caused by effects of grazing pressure and interspecies competition. Because of the high photosynthetic rate of tropical grasses (Ludlow and Wilson, 1968) and rapid seasonal growth rates (Bryan and Sharpe, 1965), the grazing pressure on components of the pasture changes markedly during the year, and is greatest on the legume in winter and early summer when growth is least.

In grazing trial no. 2, the greater animal production from pastures receiving phosphate and the legume components suggests that both P and the legumes play an important part in the level of animal production.

The effect of P in increasing dry matter production and P content of legumes are well demonstrated by the results of Andrew and Robins (1969c). These workers also obtained a good correlation betwen P and N concentrations in plant tops. Similarities of data were again obtained in the conditions of the Brazilian cerrados, when using fertilized grass-legume associations (Tables A-9 through A-12).

Estimated Net Incremental Benefits with Pasture Improvements in Central Brazil

The evaluation of grassland productivity is quite clearly an exercise in decision-making under conditions of uncertainty (Morley, 1978).

From the liveweight gain obtained so far (Table 10), it must be borne in mind that they are preliminary in nature for grazing trials because pastures should be evaluated for at least 4 to 5 years to assess productivity plus long-term stability. These trials, therefore, are still in progress.

This discussion centers on specific research findings which may not be applicable in dissimilar conditions. Care should be taken in projecting similar cost-benefits in untested areas or conditions.

It is the purpose of this discussion to attempt to assess the economic viability of beef production from pasture systems. As such, the basic assumption is that both types of pasture systems would entail the same costs of necessary infrastructure. These infrastructure costs were prorated over a 10-year period but the remaining developmental costs were not prorated.

From the data in Table 10 it can be said that none of the systems are economical when price of beef is at Cr$ 7.00/kg. When beef prices are increased to Cr$ 21.00/kg, the highest net return was from the N-fertilized pasture system. These results are in agreement with earlier studies in Queensland, Australia, which indicated that N systems may give higher return than legume systems (Mitchell et al., 1972; Firth et al., 1974). Other studies (Nuthall & Whiteman, 1972) suggested that unless N price is low and beef price is high, N systems are less profitable. Thus commercial producers must be flexible in their approach to take advantages of changing economic conditions.

In 1976, in Brazil, beef prices were low, while fertilizer prices, and particularly N, increased over the same period, so that it is unlikely that any production system would be profitable when beef prices are low. At 1978 beef prices, all systems appear attractive as investment opportunities, provided the market value of the land is not forced to prohibitive levels.

All systems are very sensitive to beef prices and cost changes. The problems that are faced by potential investors in the agricultural sector and by ranchers are to a large extent associated with uncertainty as to future project net income. It is against such a background that the various grazing systems should be viewed. This illustrates the difficulty of making generalized comparisons between production systems. Nevertheless budgetary comparisons can be made within a particular region at a given point of time.

To this end, the purpose of this study was to collect data regarding the costs and returns of tropical pasture improvement in the cerrados of central Brazil and to draw attention to the many important questions that further research may help to solve.

These two experiments represent a remarkably clear-cut example of the impact of an introduced high-quality pasture upon a

Table 10. Estimated net incremental benefits with pasture improvements in central Brazil

	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM 4
	Unfertilized Jaragua-grass pasture	Green Panic plus legume seeds plus fertilizer	'Guiné' grass plus legume seeds plus fertilizer	'Guiné' grass plus fertilizer
		(P)	(P)	(N)
Stocking rate steers/ha	1.50	2.38	1.80	2.38
Beef sold annually kg/ha	87	195	245	295
Liveweight gain kg/head	125	150	208	218
Incremental weight sold/year[a]				
at Cr$ 7.00 per kg	609	1,365	1,715	2,065
at Cr$ 21.00 per kg	1,827	4,095	5,145	6,195
Approximate development cost per hectare--$[b]	2,407	3,596	3,776	4,776
Liveweight price per kg required to break even	27.67	18.44	15.41	16.19
Incremental net return per hectare				
at Cr$ 7.00 per kg	-1,798	-2,231	-2,061	-2,711
at Cr$ 21.00 per kg	- 580	- 491	1,369	1,419

[a] Assuming the price of dressed meat to be Cr$ 105.00 and Cr$ 315.00 per arroba (15 kg of dressed meat) and dressing percentage to be 54%.

[b] Complicating factors such as interest on fertilizer investment, capital rationing and risk are disregarded in this presentation. Infrastructure costs are prorated over a 10-year period. Other costs involved in the establishment of the pasture system were not prorated in the calculations.

traditional pasture system. The reasons for the clarity of response are fairly simple: the level of animal production in the original native pasture of the cerrados in central Brazil is very low, and the quality of the introduced species, under the prevailing climatic conditions, is adequate for beef cattle liveweight gain for most of the year.

The direct applicability of put-and-take procedures to commercial situations depends on the range of management practices available, their decision intervals, and the frequency with which stocking rates are altered in the experiment. The applicability gap may be quite small for many dairying situations, and with intensive beef production where management techniques with a short decision interval, e.g., N fertilizer, are used.

The considerations which affect a farmer's ability to alter the grazing pressure do not disqualify the put-and-take technique as a valid means of obtaining constant conditions when investigating basic pasture-animal relations.

Some references from the Australian literature have stressed the need for a second generation of grazing experiments to investigate finer details of the forage-animal complex than can be studied with the classical, long-term fixed stocking rate designs. Experiments must accommodate pasture management practices where stocking rates can be altered to investigate the best grazing pressure for pastures or animals in different seasons. Willoughby (1959) has reported that whenever possible adjustments of the stocking rates to seasonal and annual changes in pasture quality and quantity are made, a high degree of pasture utilization may be achieved.

As discussed by Morley and Spedding (1968), research results may be of limited relevance to real production systems unless the experiment represented a complete production system or a reasonably self-contained portion of such a system.

Morley and Spedding (1968) questioned the appropriateness of the results of "put-and-take" experiments to grassland evaluation. The arguments have not been accepted by some writers.

Ten years later, Morley (1978, p. 151) stated that

> . . . there are at least two production systems in which "put and take" techniques may be perfectly valid. This may be so . . . on farms where most pastures are relatively poor but are being improved, the production system on the farms consists of the animals, and the areas of improved and unimproved pastures. The former area will usually be superior in respect to both quality and quantity. It would then be perfectly valid to vary the stocking rate on the improved area in order to maximize production from the total system.

The grazing trials reported here are believed to be examples of Morley's approach. From the same paper by Morley (1978, p. 152) it is quoted

> The development of optimal strategies for the use of limited areas of improved or special-purpose pastures by such means remain a high priority where pasture improvement is still a major activity. "Put and take" techniques could well be the main method of evaluation, rather than the techniques, used by most investigators, that are appropriate to wholly improved areas. But it is most important that the "put and take" on some pastures, and "take and put" on others, were evaluated as total systems.

The grazing trials conducted in central Brazil, of which two are reported here, may well be considered a reasonably self-contained portion of a complete production system.

CHAPTER V

SUMMARY AND CONCLUSIONS

Two grazing trials were conducted at private ranches in central Brazil to measure the effects of pasture attributes on beef production.

In the first grazing trial, located in the state of Minas Gerais, the area was cleared from the original cerrado vegetation and planted with a local cultivar of guineagrass *Panicum maximum* cv 'Guiné' with N fertilizer (100 kg N/ha) or with a mixture of legumes (*Macroptilium atropurpureum*, *Glycine wightii* and *Stylosanthes guianensis*). The pastures were fertilized with P and K for pasture establishment. A complete random design with two replications was used. The experimental period started on 3 October 1975 and continued for 11 consecutive months. The steers used in the experiment were Gir x Holstein crossbred steers, and grazed the pastures under the adjusted stocking rate method.

The following parameters were measured: liveweight gain/animal, animals/hectare and liveweight gain/hectare. The steers were weighed at the 28-day intervals at the same time of day after 16 hours without feed or water. Measurements of botanical composition were performed every month during both seasons. Subsamples of plucked forage were used for quality analysis in the laboratory. The relationships of animal production with forage parameters are discussed.

The results indicated that the grass N-fertilization treatment resulted in a stocking rate higher than the grass-legume treatment. Animal performance was affected by treatment and by seasonal conditions. Gir-Holstein crossbred steers were able to produce up to 453 and 547 kg/ha/year in the grass-legume and in the N-fertilized grass pasture, respectively. When each season was considered separately, there was essentially no difference between the two treatments in the daily gain per animal.

Determinations of botanical composition indicated that Glycine wightii was the most persistent of the legumes used in this experiment. Quality of forage removed by the steers in the mixed pastures was not a limiting factor for cattle growth, as indicated by the Ca, P, and protein composition of hand-plucked forage samples.

An attempt was made to assess the economic viability of beef production from the two pasture systems. The breakeven liveweight prices were calculated and both systems were very sensitive to beef prices and cost changes.

In the second grazing trial, animal production and pasture attributes were studied over a 2-year period at the ranch level in the state of Goiás, Brazil. The objective of this grazing study was to compare beef production on an improved pasture system using green panic and legumes with fertilization vs. one which represented the commpon practice of unfertilized jaraguagrass. Pastures were arranged in a completely random design. Cattle available for the experiment were Nellore and Nellore x Chianina steers. Measurements of botanical composition were also performed during the duration of the trial and the chemical composition of hand-plucked forage was determined.

Liveweight gain, expressed as an annual average for the 2 years was 161 kg/ha for the unfertilized jaraguagrass and 361 kg/ha for the fertilized grass-legume pasture. The combination of higher gains per head with the fertilized legume mixture, plus higher stocking rates led to large increases in gain per hectare. A mean stocking rate of 2.38 steers/ha was obtained over the 2 years of the trial for the grass-legume combination. For the untreated grass pasture a stocking rate of only 1.52 animals/ha was achieved.

Overall Centrosema pubescens had a higher persistence and contributed to the higher animal production in the grass-legume pasture. Starting with 36.8% in the pasture, Stylosanthes guianensis decreased with each successive seasonal sampling. This was partly due to the infestation of fungal disease or the grazing management imposed. Composite forage samples were used to assess plant composition. All the forages used, except jaraguagrass, met the P and K requirement of grazing cattle for production. Calcium and Mg were adequate in all forages studied. The micronutrients Mo and Co were considered above the minimum requirements for grazing cattle. Forage Cu during the wet season was only 1.67 ppm for the jaraguagrass, which indicated a deficiency. The mean level of forage Zn was considered inadequate, except for green panic in the dry season with a Zn level of 31.1 ppm. Green panic had borderline deficient protein levels, while jaraguagrass was below the critical level in both seasons. The legumes had higher IVOMD than grasses. The data on the mineral status of the forages reported here would help to eliminate unnecessary minerals in the supplements commercially available in Brazil. However, further investigations are needed.

Costs and returns were estimated on the actual grazing trial results. The level of animal production that can be attained in the grass-legume systems in the Brazilian cerrados is partially dependent on the legume content of the pastures, the level of available nutrients and grazing management.

From the results obtained, the following conclusions can be drawn:

1. In the cerrados of central Brazil poor animal nutrition is probably the greatest limitation to production. Pasture improvement must be the first priority. Once adequate forage resources are provided, then further gains may be achieved through breeding and other management practices.
2. Legume species and cultivars should be continually introduced and their productivity and persistence evaluated under realistic conditions of grazing and fertilizer applications. It would be preferable to do much of this research under existing farming situations. With rapidly increasing energy costs there

would appear to be an urgent need for research to develop more productive, persistent and nutritious legume-based pasture systems for the cerrados of Brazil. Ability of legumes to persist under grazing is more important than yield *per se*.

3. When possible the available research data should be programmed into forage-animal systems and assessed economically in different environments.
4. There is an obvious need for closer study of the response of tropical legumes to different grazing pressures in terms of growth and persistence of different species.
5. The level of animal production which can be attained in the grass-legume systems in the Brazilian cerrados is dependent on the legume content of the pastures, the level of available nutrients and grazing management.

The general conclusion that can be drawn from these grazing trials is that the improved pasture system technology that was used produced highly productive pastures in the cerrado region of central Brazil. In fact, the results from the experiments are fairly comparable to those obtained from tropical pasture species in different locations within the world tropics.

Based on the conclusions, important considerations for the use of tropical pasture legumes are:

1. A range of legumes is required to cope with different rainfall, temperature, and daylength regimes in the wet-dry tropics of Brazil
2. The soil nutrient requirements of each species should be assessed
3. Soil nutrient deficiencies should be corrected
4. Effective rhizobium symbiosis should be attained by providing adequate nutrition for both the host and rhizobium
5. Species must be able to thrive under grazing
6. The compatability of species mixtures must be determined under grazing in a range of climatic regimes
7. The species should be able to produce seed to ensure persistence in pastures

APPENDIX

Table A-1. Rainfall (mm) distribution (grazing trial no. 1), Minas Gerais, Brazil, South America

Month	1975	1976
January	266	77
February	108	206
March	3	202
April	135	0
May	31	113
June	9	0
July	28	45
August	0	24
September	0	93
October	111	73
November	297	260
December	195	302
Total	1,083	1,395

Table A-2. Rainfall (mm) distribution (grazing trial no. 2), Goiás, Brazil, South America

Month	1975	1976	1977	1978
January		96	545	307
February		285	78	255
March		154	256	169
April		32	102	107
May		48	22	48
June		0	21	15
July		0	0	0
August		26	13	0
September		48	44	
October	100	257	158	
November	230	155	230	
December	69	228	268	
Total	399 (3 mon.)	1,329	1,737	901 (8 mo.)

Table A-3. Chemical properties of soils from grazing trial no. 1

pH	OM	P	K	Ca + Mg	Al
	%	------- ppm ------		----- meq 100/ml------	
4.6	2.52	1	76	0.90	1.90
4.9	3.03	2	73	1.90	0.60
5.3	2.75	1	100	2.10	0.30

Table A-4. Chemical properties of soils from grazing trial no. 2

pH	OM	P	K	Ca	Mg	Al
	%	----- ppm -----		---------- meq/100 ml ----------		
5.95	2.82	2	135	5.50	3.45	0.0
5.50	2.98	3	125	3.70	2.90	0.0
5.75	2.96	7	135	4.10	2.30	0.0

Table A-5. Analysis of variance for IVOMD, protein and chemical composition of forage species, grazing trial no. 2

Variable	Sum of Squares[a]					
	Species	P > F	Season	P > F	Species x Season	P > F
Degrees of Freedom:	1		1		1	
IVOMD	66.0877	0.005	34.1566	0.0358	36.8405	0.0298
Protein	276.5003	0.0001	3.1993	NS[b]	0.3899	NS
Nitrogen	7.0784	0.0001	0.0819	NS	0.0099	NS
Calcium	0.6487	0.0001	0.0301	NS	0.0576	0.0565
Phosphorus	0.0007	NS	0.0101	0.0244	0.0001	NS
Magnesium	0.0442	0.0001	0.0067	0.0056	0.0439	0.0001
Potassium	0.0013	NS	1.1664	0.0022	0.3375	0.0748
Molybdenum	0.0177	NS	0.008	NS	0.0999	NS
Zinc	301.3050	0.0001	263.0912	0.0001	135.5031	0.0020
Copper	237.7368	0.0001	4.3867	NS	8.0700	NS
Cobalt	0.6800	0.0031	0.0032	NS	0.0024	NS
Manganese	435.1237	NS	275.3527	NS	6,091.6923	0.0019

[a] Type IV SS adjusted partial sum of squares.
[b] Not significant (P>0.05).

Table A-6. Analysis of variance for protein and chemical composition of forage species, grazing trial no. 1

	Sum of Squares[a]					
Variable	Treatment	P > F	Season	P > F	Treatment x Season	P > F
Degrees of Freedom:	1		1		1	
Nitrogen	1.6702	0.00	0.6202	0.0001	0.00256	NS[b]
Protein	54.8960	0.0001	30.1167	0.0001	0.05336	NS
Calcium	0.2393	0.0001	0.0891	0.0001	0.00589	NS
Phosphorus	0.1377	0.0001	0.01921	0.0001	0.00038	NS

[a] Type IV SS adjusted partial sum of squares.

[b] Not significant (P>0.05).

Table A-7. Yearly changes in legume components, grazing trial no. 2.

Year	Steers/ha	*Centrosema*	*Stylosanthes*
		%	
1	3.33	1.15	21.44
2	1.60	14.16	2.54

Table A-8. Analysis of variance for botanical composition, grazing trial no. 2.

Source	df	SS	F	Significance level
		Stylosanthes guianensis		
Season	1	0.8663	21.01	P=0.0001
Year	1	0.2052	4.98	P=0.0311
Year^2	1	0.0151	0.37	P=0.5473
		Centrosema pubescens		
Season	1	0.5585	27.16	P=0.0001
Year	1	0.1392	6.77	P=0.0128
Year^2	1	0.0352	1.71	P=0.1978
		Panicum maximum var. *trichoglume*		
Season	1	0.05325	0.83	P=0.3679
Year	1	0.03056	0.48	P=0.4941
Year^2	1	0.1252	1.95	P=0.1700

Table A-9. Correlations among forage quality parameters, grazing trial no. 1, wet season, Panicum maximum cv 'Guiné' plus legumes

	Ca	P
Protein	.930[a] .0001[b]	.965 .0001
P	.905 .0001	

[a]Correlation coefficient (r).
[b]Probability >|r|.

Table A-10. Correlations among forage quality parameters, grazing trial no. 1, dry season, Panicum maximum cv 'Guiné' plus legumes

	Ca	P
Protein	.699[a] .0004[b]	.727 .0002
P	.895 .0005	

[a]Correlation coefficient (r).
[b]Probability >|r|.

Table A-11. Correlation coefficients among forage quality parameters, grazing trial no. 1, wet season, Panicum maximum cv 'Guiné' plus 100 kg of N/ha

	Ca	P
Protein	.951[a] .0001	.815 .0001
P	.867 .0001	

[a]Correlation coefficients (r).
[b]Probability >|r|.

Table A-12. Correlation coefficients among forage quality parameters, grazing trial no. 1, dry season, Panicum maximum cv 'Guiné' plus 100 kg of N/ha

	Ca	P
Protein	.815[a] .0001[b]	.704 .0004
P	.628 .002	

[a]Correlation coefficient (r).
[b]Probability >|r|.

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BIOGRAPHICAL SKETCH

Armando Teixeira Primo was born April 21, 1932, at Pelotas, Rio Grande do Sul, Brazil.

In March 1954, he entered the Universidade Federal do Rio Grande do Sul and received the degree of Engenheiro Agrônomo in December, 1957. Soon after graduation, he was awarded a fellowship from the Rockefeller Foundation to study pastures in Mexico for one year.

In 1959, he joined the Secretaria de Agricultura of the state of Rio Grande do Sul, as a pasture researcher. In 1964, he was granted a scholarship from the U.S. Agency for International Development to pursue graduate studies at the University of Georgia. In 1966, he was awarded a scholarship by IRI/USAID to return to the University of Georgia, where in 1967 he received the degree of Master of Science. Subsequently, he was made director of the Forage Experiment Station at São Gabriel, in the state of Rio Grande do Sul. In 1972-1973 with the aid of an assistantship from the Animal Science Department of the University of Florida and with financial support from the Conselho Nacional de Pesquisas (CNPq) he completed the course work toward the Ph.D. degree. In 1974, he joined the Conselho Nacional de Desenvolvimento da Pecuária (CONDEPE) as a pasture consultant until 1976, at which time he was employed by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) as associate technical chief of the Centro Nacional de Pesquisa de Gado de Corte, at Campo Grande, Mato Grosso. In 1978, he was granted a scholarship from Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), to return to the University of Florida to complete academic degree requirements. Presently he is a candidate for the degree of Doctor of Philosophy.

Armando T. Primo is married to the former Rosa Maria Pires Teixeira, and is father of two children.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gerald O. Mott

Gerald O. Mott, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Professor of Animal Science

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